TAMPERE UNIVERSITY OF TECHNOLOGY
Degree Programme in Information Technology

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STUDIES ON USER EXPERIENCE OF TOUCH-BASED INTERACTION WITH NFC ENABLED MOBILE PHONES

Master of Science Thesis

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ABSTRACT

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User experience has become a trend in the HCI field during the last ten years. Despite all the fuzz around the concept of user experience, developing the methodology for studying other than traditional usability aspects is in progress. New technologies and technological environments offer new possibilities for human-computer interaction. Using more versatile interaction techniques and modalities in human-computer interaction, it can be closer to human-human interaction and offer more natural and efficient ways to interact. Near-field-communication (NFC) technology has been predicted to be one of the leading technologies in the 2010's for payment and ticketing applications. NFC technology offers possibilities to exchange data by bringing two NFC compatible devices close to each other. This is called a form of touch-based interaction.

This thesis aims to broaden the scope of user experience research on touch-based interaction from the traditional usability aspects to hedonic and emotional aspects of user experience. Two studies were conducted in order to explore the user experience of touch-based interaction and to experiment novel methods and metrics for measuring and identifying user experience. The first study was a laboratory experiment with an electronic program guide for television in which user experience of speech, gesture and touch-based interaction were compared. The second study consisted of two group sessions that aimed to create novel use cases for the touch-based interaction with NFC enabled mobile phone and to explore user experience of the interaction.

Existing methods were adapted and developed further to suit the specific context of this work. Touch-based interaction is efficient and novel interaction technique that can stimulate and bring positive user experiences to the users. Thus, it should be considered as one possible interaction method when novel technical environments are designed.

Touch-based interaction seemed to be superior compared to speech and gesture in the laboratory tests. Especially the efficiency, robustness and stimulation as novel interaction method were found to be superior.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tietotekniikan koulutusohjelma
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Käyttäjäkokemuksesta on tullut trendisana käytettävyysalalla viimeisen kymmenen vuoden aikana. Vaikka käyttäjäkokemuksesta puhutaan paljon, tulee metodologiaa kehittää siten, että myös muita kuin perinteisiä käytettävyysnäkökulmia voidaan mitata. Teknologian kehittyminen mahdollistaa uusia vuorovaikutustapoja ihmisen ja tietokoneen välillä. Vuorovaikutuksesta voidaan tehdä luonnollisempaa ja tehokkaampaa käyttämällä monipuolisemmin hyödyksi eri aisteja ja vuorovaikutus-tekniikoita. NFC-teknologian (lähikenttäkommunikaatio) avulla voidaan vaihtaa tietoa tuomalla kaksi NFC yhteensopivaa laitetta lähelle toisiaan. Tämä on yksi kosketusperäisen vuorovaikutuksen muoto. NFC-teknologian on ennustettu leviävän hyvin nopeasti erityisesti maksu- ja lippusovelluksiin alkavalla vuosikymmenellä.

Diplomityö pyrkii laajentamaan kosketusperäisen vuorovaikutuksen käyttäjäkokemuksen tutkimusta perinteisistä käytettävyystekijöistä hedonististen ja emotionaalisten tekijöiden tutkimiseen. Diplomityöprojekti koostui kahdesta tutkimuksesta. Ensimmäisen tutkimuksen, joka suoritettiin käytettävyyslaboratoriossa, tavoitteena oli vertailla puhe-, ele- ja kosketusperäisen vuorovaikutuksen käyttäjäkokemusta. Testeissä käyttäjät ohjasivat television ohjelmaopasta eri vuorovaikutustekniikoilla. Toinen tutkimus sisälsi kaksi ryhmätilaisuutta, joiden tuloksena syntyi uusia käyttötapauksia kosketusperäiselle vuorovaikutukselle ja josta saatiin kerättyä kokemuksia vuorovaikutuksen käyttäjäkokemusta.

Diplomityössä kehitettiin olemassa olevia menetelmiä käyttäjäkokemuksen mittaamiseksi. Kosketusperäinen vuorovaikutus todettiin tehokkaaksi ja uudenlaiseksi vuorovaikutustavaksi, joka voi tuottaa positiivisia käyttäjäkokemuksia. Tämän perusteella sen käyttämistä kannattaa tutkia, kehitettäessä uusia teknologiaympäristöjä.

Kosketusperäinen vuorovaikutus arvioitiin selkeästi parhaaksi vuorovaikutustavaksi laboratoriotesteissä. Erityisesti sen tehokkuus, virheettömyys ja innovatiivisuus olivat selkeästi parempia kuin puhe- ja elevuorovaikutuksen.

PREFACE

Thirteen years ago, I was sweating in an entrance examination in an auditorium at Technical University of Tampere (TUT), known with Finnish abbreviation of TTKK at that time. My plans for the future were not very clear but I was optimistic to pass the examination and start a new phase in my life. That day I did not know how much TUT would offer me during the next thirteen years. During these years, I have been enjoying the bright side of the “teekkarielämä” which is the concept of student life of technical students in Finland. I have worked five years for the technical students’ well-being in the student union and in the labor union. I have been a research assistant at the Unit of Human-centered Technology almost four years and I even worked at the construction site of the university main building. All these experiences have shaped me into who I am as a person, and who I will be as an engineer with the master’s degree in science.

This thesis was done in the DIEM project that aims to design novel technical environment. Project has offered me possibilities to have a glimpse of the future. It has been inspiring to explore top of the field research in user experience and become familiar with NFC technology and multimodal interaction.

I want to thank Thomas “Tumppi” Olsson for support and brilliant comments on my thesis. I also want to thank professor Kaisa Väänänen-Vainio-Mattila for patience towards my “sometimes-slippery” writing process and for the possibilities for combining work and studies during the last three and a half years. DIEM project personnel and other colleagues from IHTE deserve my humble thank you for their support, participating in piloting the study methods and giving ideas for my thesis. Great thanks to people from TAUCHI and ISG for cooperation in the laboratory tests and for implementing the Home Media Center.

These thirteen years would have been thirty years without my family and friends. You have brought joy to my life and given your unconditional support for everything I have done. Special thanks to Annika for taking care of everyday chores at home lately. I promise to do more laundry and empty the dishwasher more often.

Finally, I want to thank the Technical University of Tampere. The spirit of the university has had an unforgettable effect on me. Fellow students, professors, janitors, researchers, and all the other: thank you for the Great User Experience.

Tampere, June 7th, 2010

Aleksi Kallinen

CONTENTS

ABBREVIATIONS

CPU	Computer
DIEM	Devices and Interoperability Ecosystem
EPG	Electronic Program Guide for Television
GUI	Graphical User Interface
HCI	Human-Computer Interaction
IHTE	Tampere University of Technology Unit of Human-Centered Technology
NFC	Near Field Communication
RFID	Radio Frequency Identifier
RF	Radio Frequency
ISG	University of Oulu Intelligent System Group
TAUCHI	Tampere Unit for Computer-Human Interaction
UCD	User-Centered Design
UI	User Interface
URL	Uniform Resource Locator
WLAN	Wireless Local Area Network

1. INTRODUCTION

This thesis is based on the research and results of the project *Devices and Interoperability Ecosystem* (DIEM). The thesis was done in Unit of Human Centered Technology at Tampere University of Technology. DIEM is a part of one of the Finnish ICT SHOK research programs that are coordinated by the Finnish Strategic Centre for Science (TIVIT). The project has over twenty company partners and six university partners. DIEM is divided in to five work packages, *building automation, public spaces, mobile mixed reality, interaction & user interface,* and interoperability. This thesis is done for the *interaction & user interface* work package. (DIEM) DIEM partners that devoted effort to research in this thesis are Tampere Unit for Computer-Human Interaction (TAUCHI) from University of Tampere, Intelligent Systems Group (ISG) from University of Oulu and VTT Technical Research Centre of Finland (VTT). I was responsible for planning and implementing two user studies with support of project manager Thomas Olsson and other DIEM project staff from IHTE, Else Lagerstam, Jani Heikkinen and Minna Kynsilehto. VTT was responsible for project management in our work package. TAUCHI and SIG were responsible for implementing prototypes evaluated in the first study of the thesis.

1.1. Motivation and Background

DIEM project aims to create the concept and implementation of generic smart space interoperability solution and platform, to be used in various domains and applications. In other words, the aim is to develop DIEM smart environment where people can act effortlessly with multi-device user interfaces and that enables easy implementation of new applications and services. (DIEM)

Interaction & user interface work package aims to understand the goals and the needs of the users in *DIEM environment*. The research conducted in this work package will produce "*evaluation methods and guidelines, novel interaction techniques for multimodal multi-device applications, develop an open and highly integrated runtime for web-oriented technologies, and enhance and promote concept formation enabling to better commercial utilization*". (DIEM) Results of this thesis will serve especially the goals of offering *evaluation methods & guidelines* and studying *novel interaction techniques*.

It has been predicted that number of NFC (near field communication) enabled mobile phones is rapidly growing during this decade. This enables the use of new interaction techniques and services in both public and home environments. (VTT 2009) Thus, touch-based interaction with NFC-enabled mobile phones is an interesting and promising novel interaction technique for smart environments.

It is natural for human’s to communicate multimodally, that is, using multiple senses as input and output channels. People “talk with their hands”, use facial expressions to send a message, tap their feet when they are waiting for someone, perceive movement in three-dimensional space through sound etc. It is said, that human-computer interaction can be more natural and efficient if the input and output utilizes multiple senses and interaction techniques. (Raisamo 1999; Reeves et al., 2004) Multimodal user interfaces are especially interesting in the novel context of smart environments as there are no universal interaction conventions and human-computer interaction can be designed from scratch.

Moving to the new millennium, the interest towards user experience and going beyond usability has been a trend in the HCI field. Usability is seen as an axiomatic feature and it is no longer adequate to design efficient and easy to use products. (Oppelaar et al. 2008) Products need to have “wow-effect”, they need to appeal to hedonic needs of the humans and bring pleasure to the users. Even though, the user experience is seen important, many current research and design still concentrates on studying traditional usability aspects such as the efficiency and effectiveness of the product. Thus, there is a need for methods and metrics for exploring the user experience. Prior research on touch-based interaction’s user experience has concentrated mainly on traditional usability metrics (Rukzio et al. 2006; Geven et al. 2007). In this thesis, I aim to broaden the scope of user experience research on touch-based interaction to hedonic and emotional aspects of user experience.

1.2. Objectives and Research Approach

The main goals for this thesis were to investigate user experience of touch-based interaction with mobile phones and to investigate methods for measuring user experience. In this thesis, touch-based interaction is defined as interaction with NFC-enabled mobile phone. The fundamental research questions in this thesis are:

> RQ1: What kinds of elements of user experience are present in touch-based interaction with mobile phones?
> RQ2: For what domains and use cases is the touch based interaction with mobile phones suitable?

Research approach in the thesis is *exploratory case study* as the NFC is strongly *contemporary* phenomenon.Case study can be defined as an empirical study that examines the phenomenon and human in certain context in order to collect versatile information with versatile methods. Yin (2003) suggests that: "*Case studies are the preferred strategy, when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon in real-life context*". In addition to *explanatory case study* described above, Yin (2003) describes *exploratory* and *descriptive* case studies. Exploratory case studies answer especially to questions *what, who* and *where*. (Yin 2003, pp.1-6)

The research included two studies conducted between May and December 2009. The first study concentrated on studying user experience of touch-based interaction in usability laboratory by comparing it with speech and gesture interaction

From the first study I gathered both quantitative and qualitative information. Quantitative information was gathered from task times, speech recognition accuracy and subjective measures of user experience attributes. Qualitative information was gathered with observing users and with interviews.

The second study concentrated on gathering new domains and use cases for touch-based interaction and identifying user experience elements that are present in touch-based interaction. Study consisted of two group sessions that used *context walk* method, developed in this thesis, as a stimulus in the group sessions. The information gathered from the second is quantitative in nature.

1.3. **Structure of the Thesis**

The thesis begins with an introduction to NFC technology in Chapter 2. Introduction includes description of standards and technical environment, comparison with other close range wireless technologies and brief summary of current NFC applications and use domains. Basics of multimodal human-computer interaction and interaction techniques studied in this thesis are presented in chapter 3. Chapter four gives an insight of what user experience is and what affects user experience.

Chapters 5 and 6 describe the two studies conducted in this thesis. These chapters consist of introduction to methodology used in the study, detailed description of the methodology and experiment implemented in a study, following the results from a study. In the last chapter (chapter 7), I discuss the results and present the conclusions as well as ideas for future research.

2. NFC TECHNOLOGY

Near Field Communication (NFC) is an extension of radio frequency identification (RFID) technology. It is based on inductive coupling, where inductive circuits share power and data in a close distance of approximately no more than 10 cm. Inductive coupled devices work at the centre frequency of 13,56 MHz. Possible data transfer rates for NFC devices are 106, 212 and 424 kbps. (ECMA-340 2004)

NFC technology can be integrated to for example mobile phones that can act as NFC devices. Two NFC devices can exchange data or a NFC device can read and write RFID tags. RFID technology is common to many people via smart cards such as electronic bus tickets or access control cards. In these cases the user has the RFID tag stored in the smart card and the reader is an analogy to NFC device. NFC devices can act also in a smart card emulation mode and they appear to the readers in the same way as smart cards. This enables using NFC devices with existing RFID applications such as electronic wallets, ticketing applications and electronic access control cards. (NFC Forum a)

2.1. Communication Modes and Two Roles of NFC Devices

NFC interface between two NFC devices can have two communication modes: an active and a passive communication mode (Figure 1). In the active mode both devices generate their own radio frequency (RF) field, whereas in the passive mode only one of the devices has power and forms the RF field. In the passive mode the device is powered by the RF field generated by the active device. (ECMA-340 2004; Philips Semiconductors, 2006)

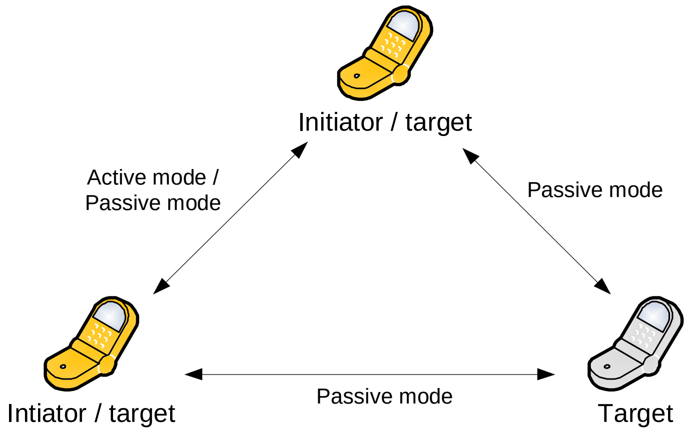

Figure 1 Modes and Roles of NFC devices

It is important to understand the different roles of the NFC devices. Device can act as an initiator (reader) or as a target. Initiator is the device that wants to communicate with the target and generates the RF field. The target receives communication request from the initiator and sends back a reply. Only the active devices can act as initiators but both active and passive devices can act as targets. In the active mode initiator is the device that starts the communication by sending a communication request. If there is no request for switching to active role from an application NFC devices act as targets by default. Two passive devices cannot communicate with each other, because there is no request to generate a RF field. (Haselsteiner & Klemens, 2006)

2.2. General Protocol Flow

Figure 2 describes the general protocol flow between two NFC devices. In the beginning both devices act as targets. If there is a request from an application one of the devices can switch to active role. Application decides the transfer speed and whether to communicate in an active or in a passive communication mode. Initiator tests if there are external RF fields present and generates RF field only if there is no other RF fields detected. This way NFC technology avoids collision between multiple RF fields. After RF field is generated, target is activated by the RF field and target sends a reply to initiator. Data exchange protocol is activated after initiator sends parameter selection request and receives reply from the target. After data has been exchanged, initiator sends requests to de-activate and release the connection and when the replies come from the target transaction ends. (ECMA-340 2004)

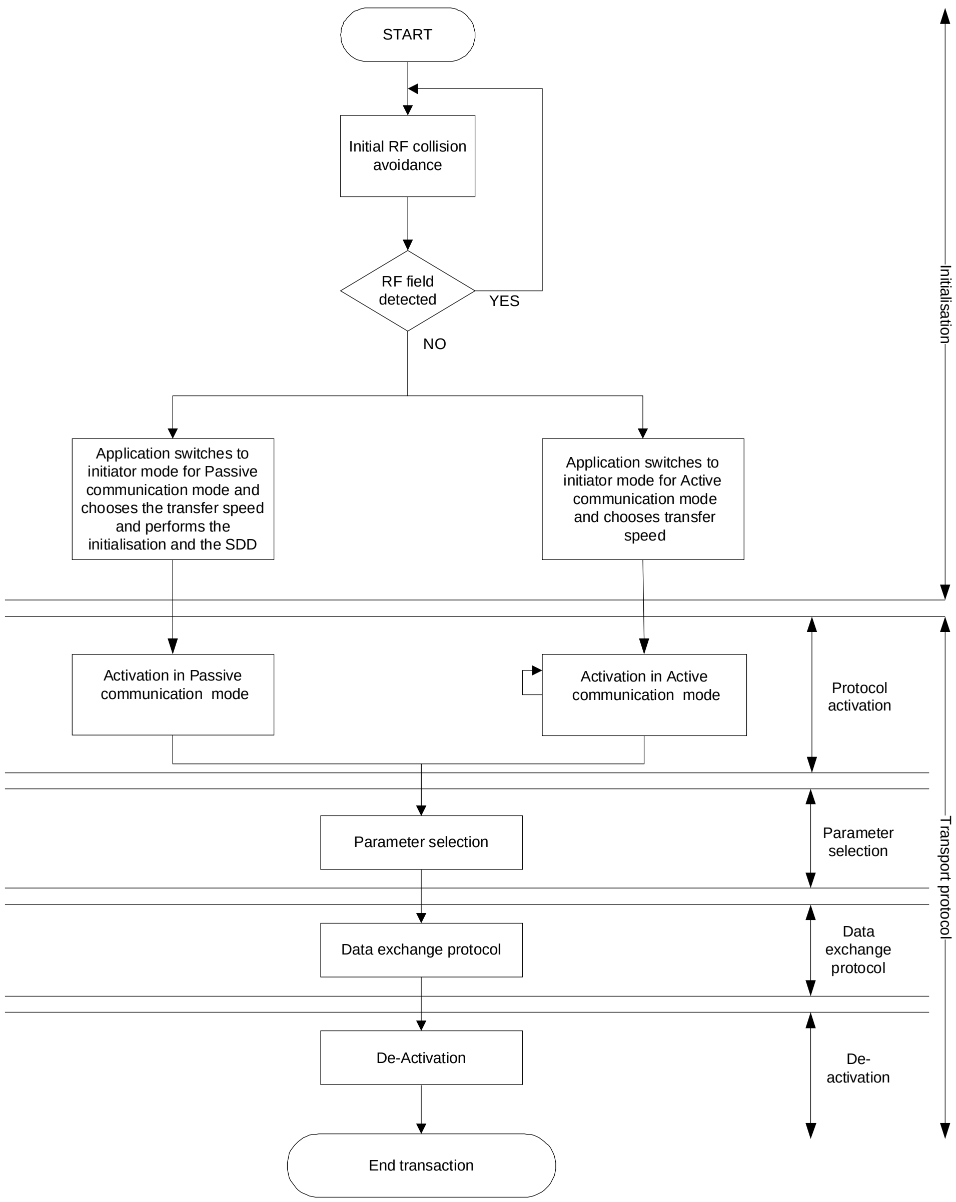

Figure 2 General Protocol Flow between NFC Devices (ECMA-340 2004)

The communication mode (active or passive) and the roles of the NFC devices stay intact during one transaction. However, the transfer speed can change depending on the parameters exchange between devices. (ECMA-340 2004)

2.3. NFC Forum Tag Types

An NFC tag is a passive device that stores data that can be read by an NFC enabled device. The Near Field Communication Forum (NFC Forum) is an industry consortium that aims to develop specifications and educate market about NFC technology. NFC Forum has more than 140 members from manufacturers and applications developers to financial service institutes. NFC Forum has mandated four types of NFC Tags (Table 1) that are recommended to use with NFC products. (NFC Forum a)

Four tag types can be divided into two groups. Tag types 1 and 2 are dual state tags. This means that these tags can operate as rewritable or as read-only tags. The user can change this state. Types 3 and 4 are single-state tags and work as read-only or rewritable tags depending on the pre-configuration by manufacturer. (Innovision Research & Technology plc, 2009)

Table 1 NFC Forum Tag Types (Radio-Electronic.com - Resources and Analysis for Electronics Engineering; Innovision Research & Technology plc, 2009)

Features	Type 1	Type 2	Type 3	Type 4
Read/write memory	96 bytes	48 bytes	1, 4, 9 Kbyte	Up to 32 Kbyte
Security	Capability for 16- or 32-byte digital signature	Unsecure	Capability for 16- or 32-byte digital signature	Variable
Unit price	Low	Low	High	Medium / High
Die size	Small	Small	Large	Large
Transfer speed	106 Kbit/s	106 Kbit/s	212 Kbit/s	106 / 212 / 424 Kbit/s

Selecting the right tag for the right purpose is important to design cost-efficient and appropriate NFC systems. Most important variables when choosing the right tag are memory size, security, price, die size and transfer speed. Type 1 and 2 tags offer small memory-capacity but are inexpensive and die size is smaller than in type 3 and 4 tags. This makes type 1 and 2 tags suitable for example storing URLs or information needed for pairing two devices with a Bluetooth connection and for user interfaces that have limited space for the tags. On the other hand, if there is need for larger memory-capacity and there for need for higher transfer speed, type 3 and 4 tags are the right choice. Use domains for type 3 and 4 tags are for example sharing pictures or ring tones in a smart poster. (Innovision Research & Technology plc, 2009; NXP Semiconducters, 2009)

2.4. Comparison with Other Close Range Wireless Technologies

Article "NFC Delivers Intuitive, Connected Consumer Experience" (Philips Semiconductors, 2006) presents a comparison between NFC, Bluetooth and Infrared close range wireless technologies (Table 2). NFC and Infrared technologies support only peer-to-peer network topology. Bluetooth allows also peer-to-multipoint networking. On the other hand NFC network is very easy and fast to setup. According to Philips Semiconductors (2006) NFC is over 3600 times faster than Bluetooth and five times faster than Infrared to setup. This is because NFC network is created by bringing devices close to one another and there is no confirmation needed to pair devices. Both Bluetooth and Infrared require choosing the wireless technology from device options by navigating through menus and/or confirmation from devices that are to be paired.

NFC technology allows communication range under 10cm, where as Bluetooth can operate up to 10m range and Infrared up to 1m range. This creates some limitations for application domains for NFC but makes NFC very suitable technology for crowded places and improves security, because forming the connection is highly visible for the user. Using NFC technology users do not need to navigate through menus and this way the interaction is faster and more intuitive. Infrared is also relatively safe because the connection requires line-of-sight between devices. The demand for line-of-sight makes Infrared connection unstable and coupling devices needs accuracy, which makes interaction more challenging. Bluetooth security is formed on application level and this is one of the reasons that makes the setup time slower. (Philips Semiconductors, 2006)

Table 2 Comparison of Close Range Wireless Technologies (Philips Semiconductors, 2006)

Variable	NFC	Bluetooth	Infrared
Network type	Peer-to-peer	Point-to-multipoint	Peer-to-peer
Range	< 10cm	Up to 10m	Up to 1m
Transfer speed	Up to 424kbps	721kbps	115kbps
Set-up time	< 0,1s	6s	0,5s
Security	Yes, hardware combined with secure card IC	Yes, software	No
Communication modes	Active-active Active-passive	Active-active	Active-active
Infrastructure	Contactless ticketing, e-payment and mobile phones	Mobile phones, consumer electronics and PC's	Consumer electronics and PC's, and mobile phones
Costs	Low	Moderate	Low

One of the most important benefits of the NFC technology is its low energy consumption. NFC devices operate in a passive mode by default and there is no need for battery when there is no NFC transaction in action. Energy is only needed when the device wants to act as an initiator or as a target in active communication mode.

Similar comparison between NFC and Bluetooth was conducted by VTT Technical Research Centre of Finland. List below presents NFC communication advantages over Bluetooth in peer-to-peer transactions:(Ailisto et al. 2007)

- NFC enables easy-to-use touch-based communication and interaction between two devices. For example, the communication can be executed or initiated by touching a fitted or portable NFC-enabled device by a hand-held NFC-enabled device.
- Communication set-up latency with NFC is typically some hundreds of milliseconds, whereas with Bluetooth it is typically several seconds.

- NFC enables longer lifetime of the battery, since the power consumption of an NFC node in passive mode can be negligible and the passive NFC node can be activated by an active NFC device (e.g. a mobile phone).
- Pure NFC communication enables lower pricing since NFC is technically less complex than Bluetooth.
- Due to its shorter range and near field coupling, NFC is more immune to eavesdropping as well as intentional or unintentional interferences.

Ailisto et al. (2007) listed also few disadvantages that are mainly consequences of the short communication range of NFC technology:

- NFC is not suitable for portable devices that require online connectivity to another portable device or to a fixed access point.
- A lower bit rate together with the short communication range can make the touch-based transfer of longer data blocks unpleasant.
- The placement of the antenna is more critical. The place of the antenna has to be indicated to the user.

These disadvantages can be overcome by combining NFC with for example Bluetooth or WLAN technology.(Ailisto et al. 2007) This is possible for example using NFC device to configure and establish a Bluetooth connection by touching a NFC tag that has connection parameters stored in it. On the other hand this means that some of the advantages, such as low cost of NFC and high visibility of connection to the user are lost.

2.5. NFC Application Domains

2.5.1. Current NFC Applications

At the moment NFC technology or compatible contactless technology is used mainly in payment and ticketing applications. Ticketing applications have been in commercial use in Japan and other Asian-Pacific countries for several years. Initially these applications were operating with smart cards based on partly NFC compatible FeliCa technology. Nowadays applications can be used also with NFC enabled mobile phones. This technology is also spreading to other commercial areas, such as restaurants, convenience stores and vending machines. (VTT 2009)

In the United States contactless payment technology has been adopted by three major credit card companies (Visa, MasterCard and American Express) and several international companies, such as 7-eleven and McDonalds. There were over 35 million contactless payment cards issued in U.S. until March 2008 and around 400 000 contactless readers located in 80 000 merchant locations. Contactless payment is still in piloting phase in Europe and commercial NFC applications have been concentrating mainly on ticketing applications in public transport and access control.(VTT 2009)

2.5.2. Future NFC Applications

SmartTouch is the largest European Union effort on piloting NFC technology and services with 215 person years from seven European countries. SmartTouch project was conducted in the years 2006-2008. (VTT 2009)

In SmartTouch project NFC applications were divided into four categories: information retrieval, value transactions, initiating action and creating social networks applications. *Information retrieval* is simply downloading information, such as web address or multimedia content from a NFC tag. *Value transaction*, that is mobile payment and ticketing, is seen as “the killer application” for NFC technology. This is because NFC is compatible with already existing RFID technology. Thus, some infrastructure for NFC *value transaction* applications is already available. It is also possible to skip the debit and credit card phase in developing countries and use NFC and mobile phone based money transactions to substitute cash. (VTT 2009)

Table 3 NFC application categories (VTT 2009)

Category	Examples
Information retrieval	• Downloading a ringtone from a smart poster • Finding timetable information on a bus stop
Value transaction	• Buying products from a vending machine • Using NFC device as a public transport ticket
Initiating action	• Ordering a pizza by touching a service tag in an electronic menu • Initiating a phone call by touching a business card • Initiating a Bluetooth connection between two devices by touching a tag that stores connection parameters
Creating social networks	• Creating a digital link between persons who meet in physical world. For example when meeting an interesting person, one can establish a digital connection by bringing her NFC device close to other persons NFC device. • This is something between traditional face-to-face communication and digital networking, such as LinkedIn.

NFC technology can be used to *initiate action* such as creating communication channel between NFC device and another device or initiating a service for example ordering a pizza with electronic menu equipped with NFC tags. Last category is *creating social networks*. This enables combining the digital or web based links and physical links. For example person could add a Facebook friend by bringing her NFC device near to another person’s NFC device. (VTT 2009)

During the project over 20 pilots were conducted in several domains, such as payment and ticketing, disabled people, health care, children, elderly people and both home and urban setting. NFC technology was used for example to:

- purchase bus tickets from a tag located in a bus stop
- enable blind people to recognize tagged objects at home
- assigning homework for upper secondary school students and help communication between home and school
- use NFC device as a remote control for multiple domestic appliances
- adapting home environment to persons profile
- health monitoring

This large variety of pilots gives an insight of vast possibilities of NFC technology. All of the application categories and pilots conducted during the SmartTouch project emphasize the intuitiveness of NFC based user interface. The use of NFC technology should enable natural, easy and effective way to achieve user's goals compared to traditional ways. For example, payment should be more intuitive, easy, secure and faster than payment with cash or a credit card.(VTT 2009)

2.6. Summary

In this chapter, I gave a brief introduction to NFC technology and its possibilities. It has been predicted that in the near future NFC technology will be available in many mobile phones. Biggest obstacle to overcome is the "egg and hen" problem. As long as there is no services the technology will not penetrate in to wider use and if there is no technology there is no market for services. Thus, it would be important to first concentrate on production services that are based on NFC compatible RFID applications.

3. MULTIMODAL INTERACTION

Chapter 3 gives an insight of multimodal human-computer interaction. First, I describe a basic model for human-computer interaction. Then I present two approaches to multimodality, *a human-centered* and *a system-centered* approach. The section 3.3 concentrates on different modalities and interaction techniques important to this thesis following a summary of the chapter 3.

3.1. Introduction to Human-Computer Interaction

Shomacher et al. (Schomaker et al. 1995, pp.2-3) present a model of basic human-computer interaction (Figure 3). There are two actors present, human and computer. Two basic processes for human are *control* and *perception*. Between the actors is user interface that can use multiple modalities for *human input* and *output*. In the basic model, there are two loops. *Intrinsic loop* describes the human action, such as eye-hand coordination and *interaction information flow* describes the human-computer interaction loop.(Schomaker et al. 1995, pp.2-3)

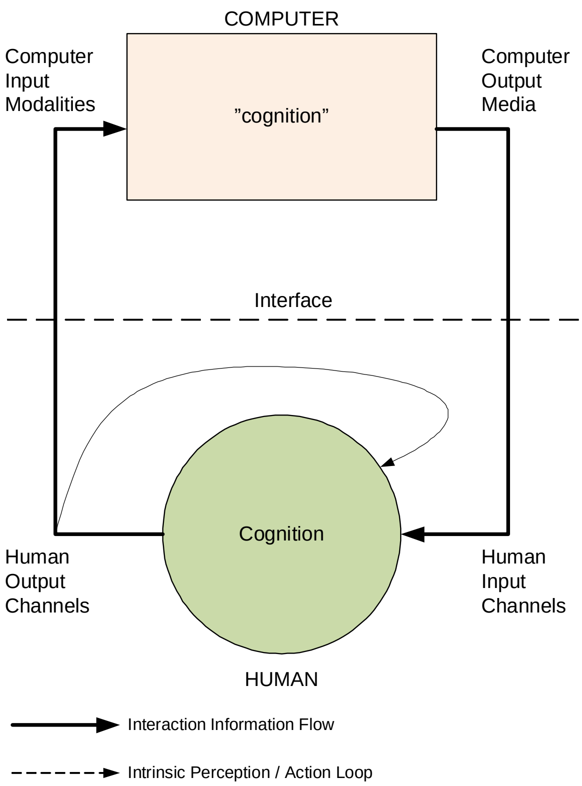

Figure 3 Basic model of human-computer interaction. (Schomaker et al. 1995)

Both actors have a cognitive or a computational component. Actors process the information from *input channels* and prepare the *output*. Schomaker et al. (1995, pp. 2-3) emphasize that it is important to notice that computer's design is known whereas human cognitive processes cannot be defined accurately.

Improving products usability aims to reduce human's cognitive load. One suggested solution to reduce cognitive load and make interaction more natural is use of multimodal user interfaces.

3.2. **Multimodal Interaction**

There are two different approaches to multimodal interaction. The first is based on psychology and concentrates on human output and input channels. In computer science, the approach is concentrated on systems that are using two or more input or output channels in order to build systems that benefit from using multiple modalities. In other words, multimodal human-computer interaction aims to make user interfaces more natural and efficient by use of two or more input and output modalities. (Raisamo 1999; Reeves et al., 2004) Human to human communication is multimodal by nature. It is said that most of the messages delivered to another person in face-to-face conversation are so called silent messages such as facial expressions and body movement. Therefore, multimodal user interfaces can be more natural to users than for example WIMP (windows, icons, menus, pointing) paradigm that is currently the most used user interface paradigm.

Raisamo (1999) presents two approaches to multimodal interaction*: a human-centered view* and *a system-centered view*. In the human-centered view multimodal perception and control, and human input and output channels, are in the focus. Perception is the process of transforming sensory input to higher–level presentations. (Raisamo 1999)

Sensory perception	Sense organ	Modality
Sense of sight	Eyes	Visual
Sense of hearing	Ears	Auditive
Sense of touch	Skin	Tactile
Sense of smell	Nose	Olfactory
Sense of taste	Tongue	Gustatory
Sense of balance	Organ of equilibrium	Vestibular
Sense of kinesthesia	Angle of joints, activities of muscels, head movements, movementes of a person within the environment, position of skin, relative to touched object	Kinesthetic

Table 4 Sensory perceptions, sense organs and modalities. Modified from Raisamo (1999).

The human-centered view concentrates on human senses. Input and output channels are sense organs that have different modalities (Table 4). (Raisamo 1999) In addition to original list of modalities, I added modality of kinesthetic to the Table 4. Kinesthesia is human perception of body movement and is there for important modality in gesture and touch-based interactions. (Schomaker et al. 1995)

The system-centered view of multimodal human-computer interaction comes from a field of computer science. It is concentrated to systems that offer multiple input devices or using multiple modalities for input with one device.

3.3. Modalities and Interaction Techniques Studied in This Thesis

In this thesis, I concentrate studying user experience of touch-based interaction with NFC enabled mobile phones. We arranged a study in usability laboratory in order to compare user experience of speech, gesture and touch-based interactions (see Chapter 5). In this section, I describe basics of these input methods.

3.3.1. Touch-based Interaction with Mobile Phones

Touch-based interaction with mobile phones is done via NFC technology. Even though touch-based interaction does not need physical connection between a mobile phone and a RFID tag, this interaction method is referred as touch-based rather than pointing. Pointing means usually interaction from longer distance than few centimeters. Pointing also requires line-of-sight with the object unlike touch-based interaction. (Rukzio et al. 2006) Good example of pointing interaction is the infrared key used to open car doors.

When a person touches for example a button with her finger, user receives tactile feedback from the contact with the surface. In case of touching or bringing mobile phone near to a RFID tag, tactile feedback is missing. Thus, it is important to give user feedback through some other modality. Feedback can be for example haptic by vibration or auditive, for example a beep.

Rukzio et al. (2006) compared three physical mobile interaction techniques: touching, pointing and scanning. Scanning offers user a list of nearby smart objects via wireless technology, such as Bluetooth. User can select an object and gets a listing of its services. Rukzio et al. (2006) studied these interaction techniques with web questionnaire, low fidelity and high fidelity prototypes.

Table 5 Comparison of properties of the physical mobile interaction techniques. (Rukzio et al. 2006)

	Touching	Pointing	Scanning
Natural Interaction, Intuitiveness	Good	Good	Average
Felt error resistance, non-ambiguous	Good	Average	Bad
Cognitive load	Low	Medium	High
Physical Effort (outside interaction distance)	High	Medium	Low

Table 5 presents the summary of the findings from the studies. Touch-based interaction was found to be natural and intuitive, robust, very quick and non-ambiguous interaction technique, which can require physical effort. Touching and pointing are recommended interaction techniques whenever there is a line-of-sight with the object and scanning should be avoided as much as possible. Rukzio et al. 2006 found out that users' motivation to make any physical effort is generally low. Thus, touch-based interaction should be used when the object is within the reach of the user, because it is more robust, effective and requires less cognitive effort than pointing. Pointing is suitable when the object can be seen but is not in close reach. (Rukzio et al. 2006)

3.3.2. Speech & Gesture

Rosenfeld et al. (2001) present three fundamental advantages for speech user interfaces:

1. Speech is an ambient medium rather than an attentional one.
2. Speech is descriptive rather than referential.
3. Speech require modest physical resources

Speech allows people to interact while using other modalities to do something else. For example, visual activity requires user's focused attention. Thus, speech can be referred as an ambient medium. Compared to for example pointing and grasping, in visual situations, speech is on a higher abstraction level and is used to describe objects by their roles and attributes. Thus, Rosenfeld et al. state that speech and pointing can often be successfully combined. Speech also requires very little physical resources. (Rosenfeld et al., 2001) For example, user interfaces with speech input can be designed for physically and visually impaired people (Turunen et al. 2009c).

Gestures are natural part of the human to human communication. Often people strengthen the message of what they are saying with gestures of hands and arms. Gestures can be used to unimodal interaction as well. For example in a crowded and noisy bar, one can order a large beer by making a gesture describing the height of the mug to the bartender. Sign language that is used by people with impaired hearing is another good example of using gestures in human-to-human communication.

Sowa (2008) states, that speech and gestures are considerably different. Speech packages content in linear symbolic form, whereas gestures include meanings in three-dimensional space. (Sowa 2008) Because these modalities are different they can be used to complement each other in multimodal human-computer interaction.

Sowa (2008) divides gesture signal capturing sensors in to two dimensions, active vs. passive and invasive vs. non-invasive. Active sensors, such as accelerometers, sense the gestures themselves. Passive sensors use markers are captured for example with machine vision or in other ways. Invasive methods use active devices or hands and arms mounted with passive markers. Non-invasive methods are usually based on machine-vision and gestures are captured externally. (Sowa 2008)

3.4. Summary

Many studies of touch-based interaction with NFC mobile devices have been conducted. Most of them emphasize that touch-based interaction is seen as quick, intuitive, and mentally inexpensive interaction technique. Biggest challenges seem to be how the affordances can be communicated to the users to support forming the mental model of touch-based interaction and how to reduce skepticism towards security of NFC and social acceptance of touching surroundings with a mobile phone. (Rukzio et al. 2006; Geven et al. 2007; O'neill et al. 2007; Iglesias et al. 2009; Hardy & Rukzio 2008)

Speech and gesture interaction techniques complement each other very well in multimodal user interfaces. Speech is suitable for descriptive inputs and gestures can be used for mediate meanings three-dimensional space. (Kazi et al. 1998; Rukzio et al. 2006; Sowa 2008)

4. USER EXPERIENCE

This chapter concentrates on describing different approaches to user experience. In the beginning of the chapter I present how the HCI field has developed from early 1980's to the current day. Section 4.2 concentrates on the definitions of user experience. Section 4.3 describes different approaches, theories and frameworks for user experiences. In the end of this chapter, the definition for user experience that is used in this thesis is presented.

4.1. Towards Designing for User Experience

Jordan (2000) describes the road towards user experience research and implementation in the field of HCI by three phases (Figure 4) starting from 1980's and ending to the new millennium. In the early 1980's there started to be more and more HCI specialists but companies did not take the advantage from their professional skills. Instead of focusing on users and human factors the development emphasized technological aspects. Moving towards 1990's HCI specialists were asked to add a nice interface to an almost-ready-product. The work was still somewhat superficial although the need for good usability was recognized and more HCI specialists were employed in the industry. At the end of the last millennium companies started to understand that good usability of the products can also lead to good sales and user-centred design (UCD) practices were implemented in HCI mature companies. (Jordan 2000)

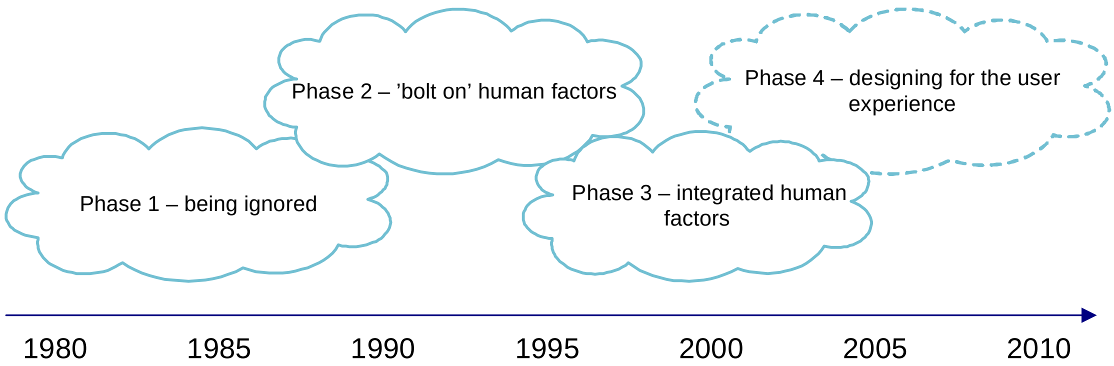

Figure 4 Development towards designing user experience adapted from Jordan (2000).

In the Figure 4 in addition to Jordan's (2000) three phases there's a fourth phase – designing for the user experience - added by myself. The phase designing for user experience is still in progress. It describes the challenges of the new millennium: How to face the demand for products that have good user experience and evoke positive feelings and bring pleasure for users?

Jordan (2000) states that users will demand more than just good usability from a product, pleasure - that is good user experience. He suggests that whilst the usability of products has improved significantly, users (consumers) have become more demanding. Blythe et al. (2003) state: “Now it’s no longer adequate just to avoid bad experiences, we have to find methods for designing good ones”. According to Oppelaar et al. (2008) products are at the present time seen as a medium for constructing an experience compared to traditional way of keeping the products and their features themselves in focus. Thus good usability is seen as an axiomatic feature in a product and it is not enough when designing successful products.

4.2. Definition of User Experience

In the ongoing years user experience has become more and more important research area in HCI field. Although there has been published plenty of research on user experience there is still no common understanding on what user experience really is (Oppelaar et al. 2008; Roto et al. 2009). Hassenzahl and Tracinsky (2006) describe user experience as a strange phenomenon that has overtaken the field of HCI, both practitioners and researchers, by a storm over the last fifteen years. By using word “strange” they emphasize the large variety of studied user experience aspects and absence of common theoretical framework for user experience. User experience can be seen for example as a temporal phenomenon, it is associated with emotions, hedonic aspects such as beauty and pleasure or it can be seen as an extension to traditional usability (Hassenzahl & Tractinsky, 2006).

To gain an understanding on current views on user experience and to support creating common definition for user experience, Law et al. (2009) conducted a research and gathered opinions from 275 HCI researchers and practitioners. User experience was seen dynamic, context-dependent and subjective phenomenon and it was seen important that user experience must be a part of HCI field’s scope of interest. To clarify differences between the concepts of user experience and other experiences such as brand experience, service experience or plain experience, Law et al. (2009) recommend that user experience is scoped to products, systems, services and objects, that user interacts with via user interface (Figure 5).

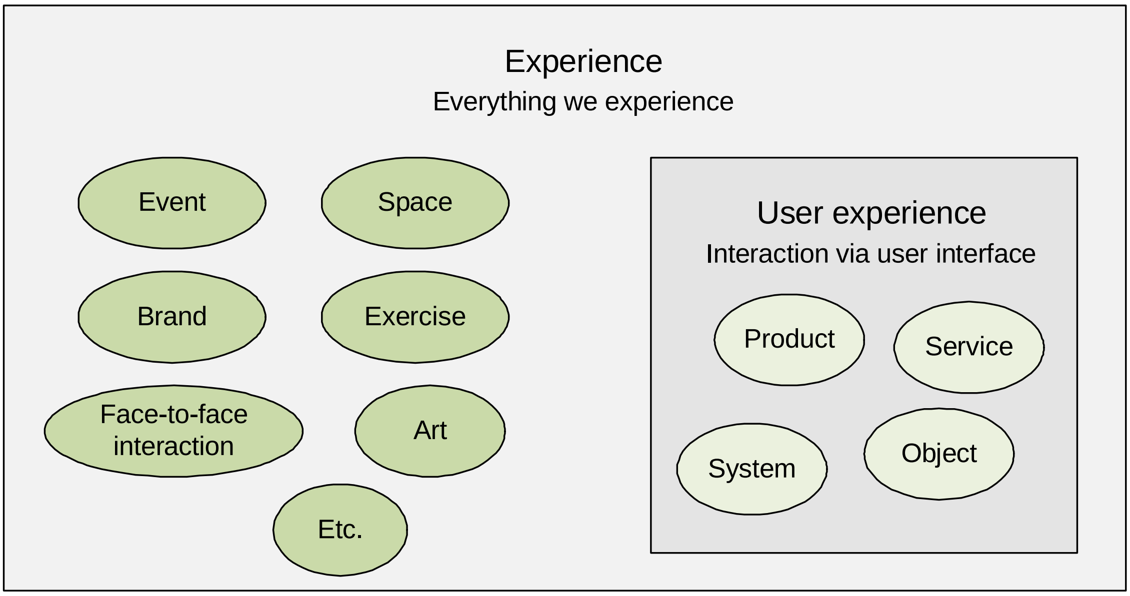

Figure 5 Relation between user experience and other experiences (Law et al. 2009)

Law et al. found out that researchers' and practitioners' opinion matched quite well with new ISO standard (ISO9241-210 2009) for user experience: "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". Product, system and service mentioned in standard can be found also in Law et al.'s (2009) recommendation for user experience. Standard focuses on the immediate consequences of use (perceptions and responses) and somewhat ignores the temporal nature of user experience (see 4.3.4 Temporal Nature of), however the concept of *anticipated use* can be seen related to pre-use expectations.

4.3. User Experience Frameworks and Theories

As mentioned earlier, during the last decade there have been published lots of research of user experience. This chapter represents four frameworks and theories important for this thesis. First two define the characteristics and dimensions of experience and latter two concentrate on what affects user experience.

4.3.1. Nature of Pleasure

Jordan (1999) defined pleasure with products as: "the emotional, hedonic and practical benefits associated with products". Practical benefits are outcomes of product use. For example if using a TV electronic program guide (EPG) is efficient and effective, it gives user practical benefits. Emotional benefits occur when product evokes positive emotions and gives satisfaction to the user. For example playing a video game can be fun and exciting. Hedonic benefits are related to the aesthetic and sensory pleasures. If remote control is well designed, it fits 'like a glove' into the users hand and the materials can give pleasant sensation when holding the remote control or pressing the buttons. Remote control can be designed also in a way that it gives aesthetic pleasure and fits the interior of the living room. (Jordan 2000)

In the book “Designing pleasurable products” Jordan (2000) argues that HCI field should move beyond traditional usability aspects that are quite limited to studying cognitive and physical aspects of human computer interaction. Thus, he presents a framework for considering pleasure with products. Framework is meant to help to gain more holistic view of the relationship between users and products. Framework consists of four aspects of pleasure (Table 6) that are based on anthropologist Lionel Tigers (VIITE) research. Jordan discusses these aspects especially in a context of product design.

Further on pleasure can be divided to need pleasure and pleasure of appreciation. Need pleasure is something that is achieved when lack of some aspect of pleasure is fulfilled. Pleasure of appreciation is something extra that is not necessity to fulfill any specific need. (Jordan 2000) Table 6 describes the relationship between four aspects of pleasure and need pleasure and pleasure of appreciation.

Table 6 Relationship between four aspects of pleasure and need pleasure and pleasure of appreciation (Jordan 2000)

Aspects of pleasure	Need pleasure	Pleasure of appreciation
Physio-pleasure	Sleeping in a comfortable bed	Visiting a spa
Socio-pleasure	Keeping in touch with family members via e-mail	Show off to friends with new mobile phone
Psycho-pleasure	Learning new things every day	Solving the Rubik’s cube
Ideo-pleasure	Performing at work so that one is appreciated by co-workers	Helping co-workers proactively

Physio-pleasures are pleasures that are experienced through sensory organs and are mediated through for example haptic, tactile, olfaction, gestation or vestibular-modalities. (Jordan 2000) For example sleeping in a comfortable bed fulfills the physiological need for rest. Spending few hours in a spa is not necessity but can give pleasure of appreciation.

Keeping in touch with close friends and family can be important social need for an individual. Writing an e-mail or making a phone call to family member can thereby fulfill the need and give socio-pleasure. Showing off to friends with new mobile phone is not something that is vital for person but it can bring pleasure of appreciation when friends admire one.

Interacting with the product can emerge emotional reactions or require cognitive work from the user. Thus, psycho-pleasure is about cognitive demands of using the product and emotional reactions that emerge from using the product. (Jordan 2000) Some people have need for constant personal self-development and they can fulfill this need and get psycho-pleasure by learning new things in day-to-day basis. Solving a logical problem such as Rubik's cube is something that can raise emotions of succeeding and therefore give pleasure of appreciation to the person.

Ideo-pleasure includes aesthetics of a product and values that the product contains. (Jordan 2000) If person's values demand high work ethics, performing well at work gives her ideo-pleasure by filling the need of appreciation from co-workers and society. Helping others can give pleasure of appreciation when person values helpfulness and friendliness.

4.3.2. An Interaction-Centred Framework of Experience

There are no many frameworks for designing user experience. Trying to develop a framework for designing for user experience and understanding experience Forlizzi & Ford (2000) divided experience into three dimensions: experience, an experience and experience as story. Further on Forlizzi & Battarbee (2004) developed the framework and substituted experience as story with a concept of co-experience. These dimensions are based on multidisciplinary research on experience. The nature of experience was studied through for example cognitive science, business, philosophy, anthropology, social science and design (Forlizzi & Battarbee 2004; Forlizzi & Ford 2000). Based on these dimensions they created framework for experience that emphasizes interaction between product and user.

In an initial framework of experience Forlizzi & Ford (2000) represent a model of aspects that influence experience (Figure 6). Users act in a context of use that is shaped by social, cultural and organizational factors. (Forlizzi & Ford 2000) For example when user is watching TV there can be family or friends around, language of the EPG and TV programs are adjusted to certain language and country and TV is using different standards depending on the location.

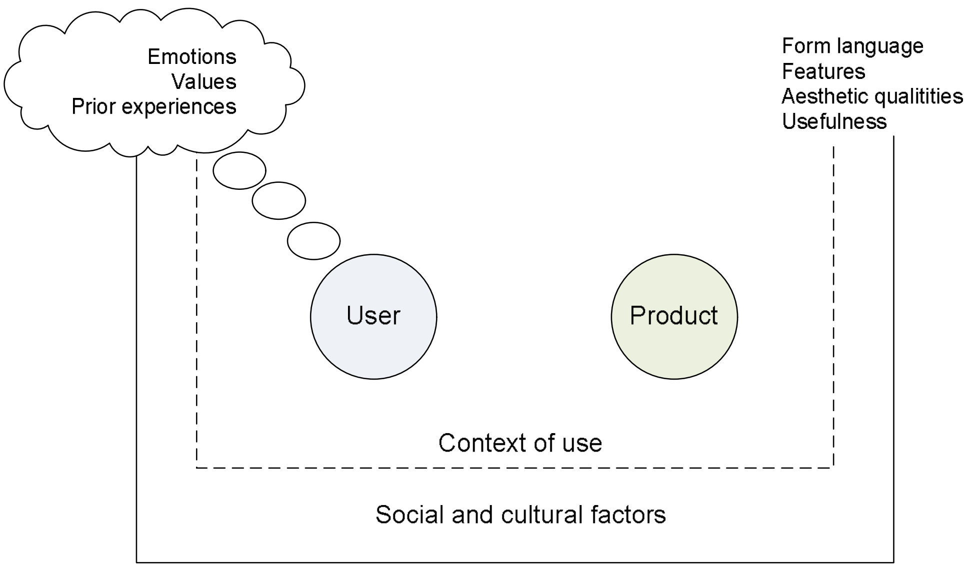

Figure 6 Influences on experience (Forlizzi & Ford 2000)

In interaction with a product, users influence experience with their prior experiences, emotions, values and cognitive capabilities. On the other hand product has certain features, look and feel and utilities that have an effect on experience. (Forlizzi & Ford 2000)

Forlizzi & Battarbee (2004) divided user-product interaction into three categories: *fluent, cognitive and expressive* (
Table 7). *Fluent interaction* is highly automated procedure and it does not demand much effort from the user. *Cognitive interaction* focuses on the product at hand. User has to use cognitive resources when using a product. *Expressive interaction* is present when user relates to a product and forms relationship to a product. (Forlizzi & Battarbee 2004) For example when user is using an TV electronic program guide (EPG) for the first time she needs to perceive available functions and form a conceptual model of how the system works. This requires cognitive resources. After a while user has learned basic features and can use the EPG almost unconsciously. Offering possibilities to personify EPG for example by giving option to form own channel collections user can form a relationship with the product.

Table 7 Interaction-centered framework of experience: types of user-product interactions (Forlizzi & Battarbee 2004)

Types of User-Product Interactions	Description	Example
Fluent	Automatic and skilled interaction with products	riding a bicycle making the morning coffee checking the calendar using EPG for changing a channel
Cognitive	Interactions that focus on the product at hand; result in knowledge or confusion and error	trying to identify the flushing mechanism of a toilet in a foreign country using online algebra tutor to solve a math problem using EPG to record a program for the first time
Expressive	Interactions that help the user form a relationship to the product	restoring a chair and painting it a different colour setting background images for mobile phones creating workarounds in complex software personifying controls for EPG

Table 8 describes different types of experiences. In the framework *experience* is narrative in nature and is described as a constant stream of self-talk that happens when one is conscious. *Experience* can be for example spending time at home watching TV. *An experience* has a beginning and an end and it can be named or specified. *An experience* often induces emotional or behavioural consequences. Using an EPG for the first time is an example of an experience. It can cause pleasure or frustration, increased or decreased use of TV.

Table 8 Interaction-centered framework of experience: types of experiences (Forlizzi & Battarbee 2004)

Types of Experience	Description	Example
Experience	Constant stream of "self-talk" that happens when we interact with products	walking in a park doing light housekeeping using instant messaging systems use life-cycle of a TV
An Experience	Can be articulated or named; has a beginning and end; inspires behavioural and emotional changes	going on a roller coaster ride watching a movie discovering an online community of interest using TV's electronic program guide for the first time
Co-Experience	Creating meaning and emotion together through product use	interacting with others with a museum exhibit commenting on a friend's remodelled kitchen playing a mobile messaging game with friends watching TV with friends

Co-experience is user experience in social context. Social context influences experience through social interaction. For example watching a horror movie alone can lead to very different experience than watching the same movie among friends. *Co-experience* is somewhat controversial concept. Law et al. (2009) address that other people influence an experience, but only an individual can have experiences and experiences are personal.

4.3.3. **What Affects User Experience?**

Hassenzahl (2004) defines a concept of product character as a summary of *pragmatic* and *hedonic* attributes. Pragmatic attributes are something, we traditionally think, have an effect on utility and usability (clear, usable, controllable, useful, and efficient). Hedonic attributes are related to pleasure and emotions and have effect on individual's psychological well-being. For example product can be regarded as impressive, interesting, exciting or outstanding. (Hassenzahl 2003b)

Hassenzahl (2004) divides hedonic attributes into three dimensions: *stimulation*, *identification* and *evocation*. Products need to be stimulating for the user, that is for example offer new ways of interaction, give possibilities to self-development and offer new opportunities and insights.(Hassenzahl 2003b) Novelty of using EPG with speech or physical touch interface can stimulate users and increase their motivation helping goal achievement.

Individuals have need to communicate their identity to others. Thus identification is entirely social attribute. (Hassenzahl 2003b) For example on a desert island there is no need to use fancy clothes or were a Rolex because there's no one to communicate identity to. Adding features that help identification with product can make products more desirable.

Products can also provoke memories. Hassenzahl (2004) mentions souvenirs as a product category that offers only symbolic value to the users. Souvenirs do not often have pragmatic value to the users but evoke pleasant memories past events.

The product character can be viewed either from a designer's or from user's point of you (Figure 7). Designer has created the *intended product character*, which is the result of features (*content*, *presentation*, *functionality*, *interaction*) that are designed in a product. Individuals perceive products always differently. Thus user's product character - *apparent product character* - is personal, depending on the situation, former experiences and state of mind. Apparent product character can also change over time and depending on the situation. (Hassenzahl 2003b) For example, if one is using a mobile phone on day time, it can be very efficient and satisfying. However, if the buttons are small and the screen is dim, using the same mobile phone can be frustrating in the dark.

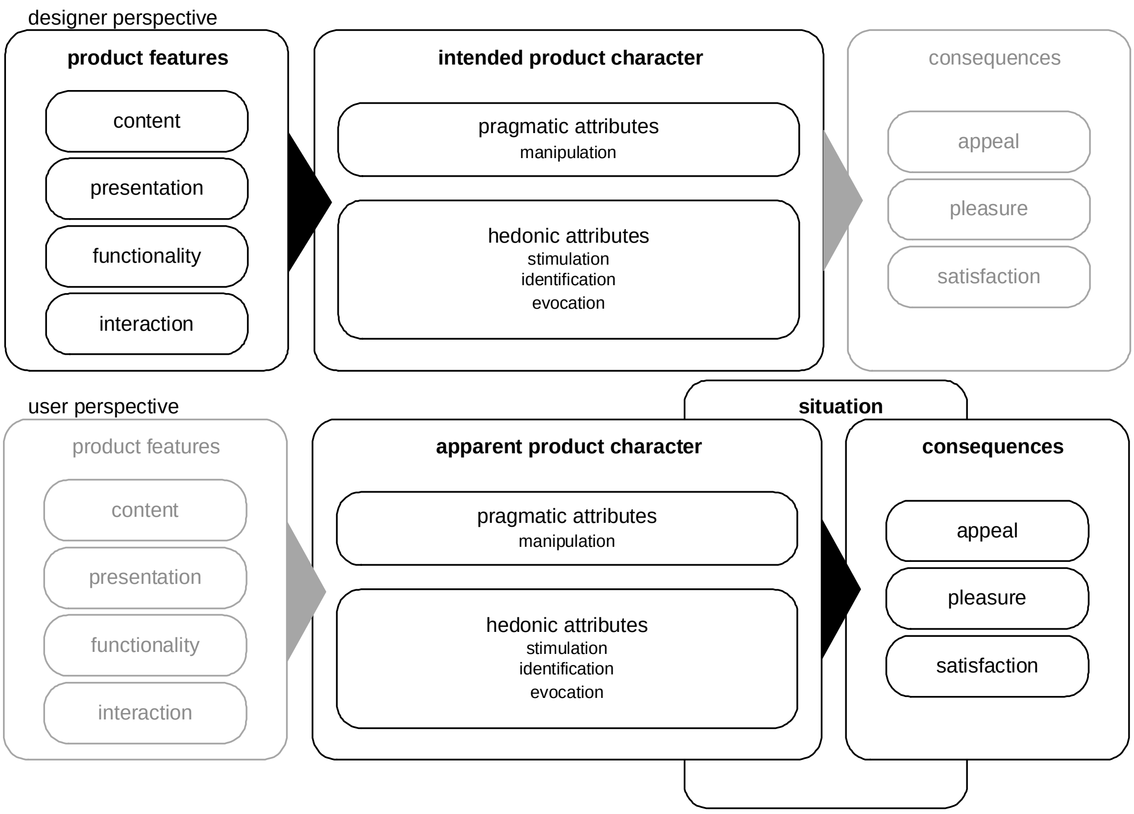

Figure 7 User experience model from the designer's and user's perspective (Hassenzahl 2003b)

In summary of *apparent product character*, including both *pragmatic* and *hedonic* attributes and use *situation* user hopefully experiences *appeal* to the product, and gets *pleasure* and *satisfaction* from using the product.

Pragmatic and *hedonic* attributes are present simultaneously. Thus Hassenzahl (2004) presents a fourfold table (Figure 8) for combining these attributes. He also defines *SELF* and *ACT product characters*. *SELF product character* is present when *hedonic attributes* are strong and *pragmatic attributes* are week. For example, if husband buys flowers to his wife, his goal is to bring pleasure to his wife, which brings pleasure to himself as well. On the contrary ACT product character is present when pragmatic goals are strong and hedonic attributes are week. If both, pragmatic and hedonic attributes are week, the product is unwanted, and if both are strong the product is desired.

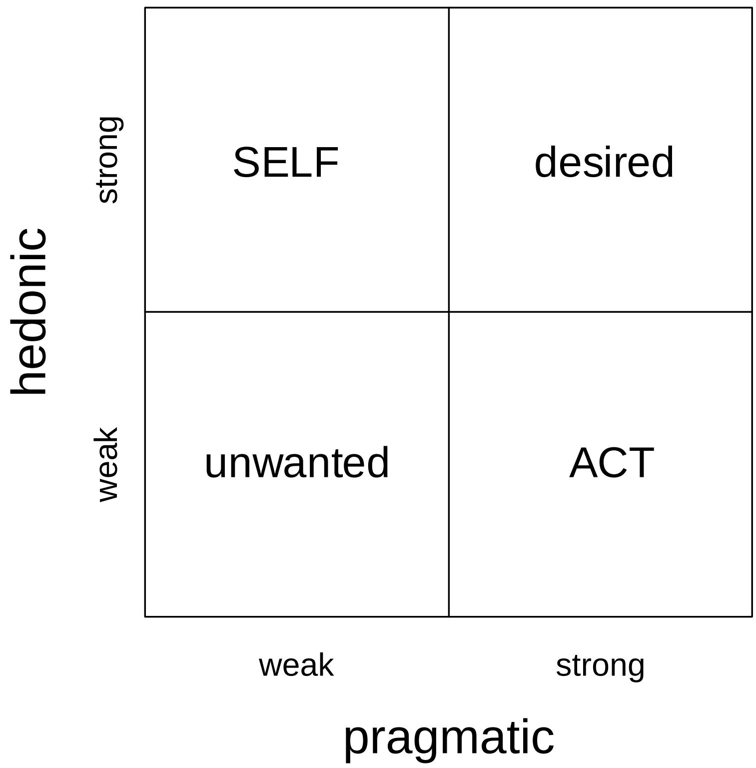

Figure 8 Product characters from combinations of pragmatic and hedonic attributes (Hassenzahl 2003b)

Because the context of use is relevant in user experience, Hassenzahl (2004) describes a model of usage modes. Modes are present in *situation* a product is used (Figure 7). Use consists of goals and actions to fulfil these goals. In goal mode, individual is trying to achieve the goal as efficiently as possible. In action mode the final goal is not as relevant as is the performing the actions. For example filling in a tax form, one is probably in a goal mode whereas writing a love letter one might be in action mode and spends hours doing it.(Hassenzahl 2003b)

4.3.4. **Temporal Nature of User Experience**

Kankainen (2003) emphasizes the temporal nature of user experience. Previous experiences and expectations are crucial for how a user experiences the use of a product. Kankainen (2003) presents a conceptual model of user experience (Figure 4) in which user experience is outcome of a motivated action in a specified context. *Present experience* is influenced by *previous experiences* and *expectations*. Present experience leads to new and *modified experiences* and *expectations*.(Kankainen 2003) For example if you are planned to enjoy a delicious dinner in a good restaurant you have high expectations towards the experience. Experience can point out to be a disappointment if the food is not outstanding although it might be basically tasty and good quality. Next time you go to the same restaurant your expectations are not that high and you can be positively surprised even if the food is not outstanding but better than the last time. On the other hand going to see a movie that has had lousy reviews can be a good experience if the movie exceeds your prior expectations.

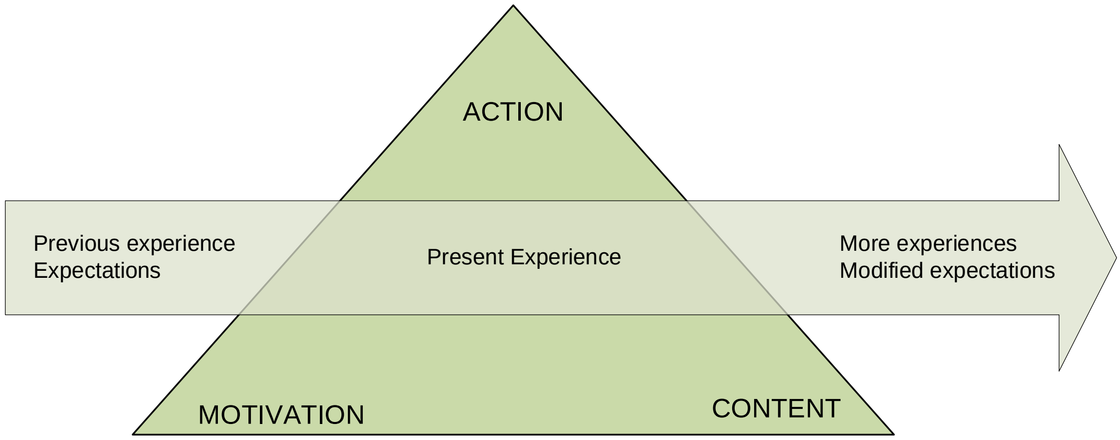

Figure 9 A conceptual model of user experience (Kankainen 2003)

Motivated action refers to users' needs. According to Kankainen (2003) motivation arises from physiological, such as hunger or thirst, and psychosocial, such as the need to enhance self-esteem, states of tension. When a need reaches sufficient level in a certain context, person has *motivation* to fulfil the need. People have also action-level needs. These needs are related to the question "how a person is doing, what she is doing". Thus action-level needs are more cognitive than motivational–level needs that answer to the question "why person is doing, what she is doing".(Kankainen 2003)

Expectations are mentioned also in other research as an important factor of user experience (Forlizzi & Ford 2000; Hassenzahl & Tractinsky, 2006; Law et al. 2009). For example Heikkinen et al. (2009) stress: "The prior expectations for the experience play a major role in determining the overall satisfaction or dissatisfaction, joy or happiness, and benefits or disadvantages of the eventual experience".

4.4. Summary

In this chapter, different qualities, theories and frameworks of user experience were described. To understand user experience of different interaction techniques we need to take in consideration different aspects of user experience. While user is using a product, she can be in an action-mode or in a goal mode. Using product can be fluent, require cognitive effort or be expressive. Social, cultural and organizational aspects are present in the use situation. Consequences of interaction can be feelings of physio-, socio-, psycho and ideo-pleasure or appeal and satisfaction towards the product used. Expectations have strong influence on user experience and experiences change over time. Product characteristics that influence user experience include both hedonic and pragmatic attributes. In addition, the subjective nature of user experience should be taken in consideration.

User experience is a versatile concept that should be approached and studied in convenient way depending on the context. In this thesis, user experience is defined the same way as Law et al. (2009). Thus, experience is on higher abstraction level than user experience and user experience occurs in interaction with a product via user interface.

5. STUDY 1: MEASURING USER EXPERIENCE IN LABORATORY

Chapter 5 describes the methodology and procedure used studying user experience of different interaction techniques in laboratory environment. I measured user experience of speech, gesture and touch-based interaction with an electronic program guide (EPG) which is part of the Home Media Center developed at TAUCHI. Tests took place in June 2009 in IHTE usability laboratory at the Technical University of Tampere. In the first section, goals of the study are presented. The second section gives an insight to the theories and methods behind the methodology used in this study Section 5.3 describes the Home Media Center user interfaces. In section 5.4, the applied methodology is described in detail as well as participants following the description of methods used in analyzing of the results. Last section of this chapter presents the results of the study.

Chapter 5 presents the study conducted between April and June 2009. First, I define the goals of the study and present an introduction to the methodology the laboratory tests were based on. In section 5.4 I describe the methodology applied in this study following the description methods used

5.1. Goals

Main goals for this thesis were as follows:

Goal 1: Measuring user experience of touch based interaction in usability laboratory and developing metrics for measuring hedonic aspects of user experience in addition to pragmatic aspects.
Goal 2: Comparing user experience of touch-based interaction technique with speech and gesture interaction techniques
Goal 3: Gathering general opinions and use case ideas for touch-based interaction with mobile phones

5.2. Introduction to Used Methods

5.2.1. Usability Testing in Laboratory

Usability testing in laboratory is efficient way to study certain usability issues. Laboratory tests require normally relatively small number of participants, typically four to ten. The most important metrics collected in laboratory tests are usability issue frequency, type and severity.(Tullis & Albert 2008, p.57) Tullis & Albert (2008, p.99) define usability issue as follows:

"A usability issue might involve confusion around a particular term or piece of content, method of navigation, or just not noticing something that should be noticed."

Other metrics for which data can be collected are for example task success, errors, time-on-task, learnability and efficiency. Tullis & Albert (2008, p.57) emphasize that the performance data should be approached carefully because the risk of over generalizing the results to the larger population. They suggest that reporting only frequency of successful tasks or errors is enough in many cases. (Tullis & Albert 2008, p.57)

5.2.2. Measuring Pragmatic and Hedonic Quality of User Experience

Based on his model of user experience (see section 4.3.3) Hassenzahl (2003) developed AttracDiff 2 questionnaire for measuring pragmatic and hedonic qualities of user experience. AttracDiff 2 questionnaire consists of 21 attributes that are divided in to three groups: hedonic quality-identification (HQI), hedonic quality-stimulation (HQS) and pragmatic quality (PQ). In order to measure hedonic quality attributes of user experience I derived metrics from Hassenzahl et al. (2003). I translated attributes from German and English to Finnish. Attributes are measured with bipolar semantic differential on a one to seven point scale (Hassenzahl, 2004).

5.2.3. Comparing Experience to Expectations

User experience has temporal nature, as presented in section 4.3.4. Turunen et al. (2009a) have developed a method called SUXES for measuring pre-use expectations and post-use experiences. The SUXES method is developed in order to measure user experience efficiently. Evaluation process is also partially automated. The method is developed especially in a domain of speech and multimodal user interfaces. (Turunen et al. 2009a) SUXES method is based on a method for measuring service quality called SERVQUAL (Parasuraman et al., 1988).

The SUXES method consists of several web questionnaires and wizards and user experiment. The first phase –Background information - consists of an introduction to best practices in usability evaluations (step 1) done with web wizard, a background web questionnaire (step 2) and possibly reservation of the actual test via web wizard (step 3).(Turunen et al. 2009a)

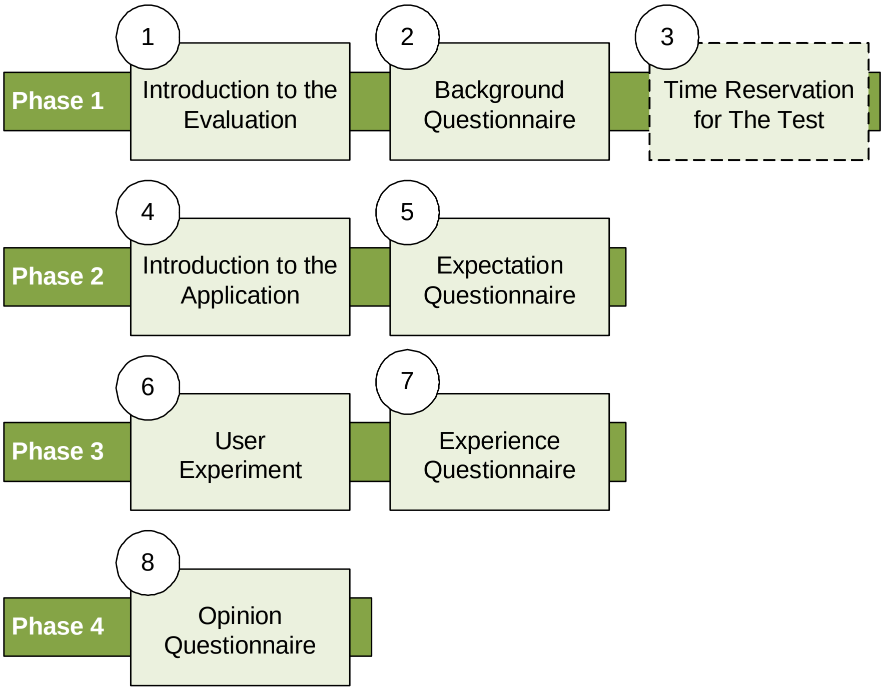

Figure 10 SUXES evaluation procedure (Turunen et al. 2009a)

The second phase - user expectations - consists of introduction to the studied application with multimedia instructions (step 4). Turunen et al. (2009a) have used for example web pages and multimedia introduction with videos. Turunen et al. (2009a) emphasize that it is important to give a realistic view of the application and its output and input modalities to the participants but not to give specific usage instructions. This is important in order to capture expectations accurately without overwhelming the participant with detailed instructions. Based on the introduction, participants fill in web questionnaire of expectations towards the studied application.(Turunen et al. 2009a)

Expectations towards a modality are inquired with a scale from one to seven. User chooses an acceptable level and a desired level for each statement. This is adopted from the SERVQUAL method (Parasuraman et al., 1988). The acceptable level is the lowest level that is adequate to the participant and the desired level is the level that is not worth exceeding in participants opinion. (Turunen et al. 2009a)

Turunen et al. (2009a) have defined a set of nine statements that relate to speed, pleasantness, clearness, error free use, robustness, learning curve, naturalness, usefulness, and future use. For example a statement “Speech input is efficient to use” is meant to measure efficiency of the speech input. Turunen et al. (2009a) emphasize that it is important that the same statements can be used for every measured input and output modality.

The third phase - experiment and user experience - includes the actual usage of the application (step 6) and filling in the web questionnaire of user experiences (step 7). In the step six, web wizard presents task descriptions to the participant. In the conducted studies there has been a test moderator present to whom the participant can turn to when there is questions or problems during the test. After the actual use of the system, participant fills in an experience questionnaire that has the same statements as the expectations questionnaire. For experience questionnaire, participant gives only one value for the perceived experience. (Turunen et al. 2009a)

The last phase – feedback – can be used for gathering experiences of the test procedure and general feedback about the system. This is normally done with the feedback web questionnaire (step 8). The step eight can also be replaced with a short interview. (Turunen et al. 2009a)

5.3. The Home Media Center

5.3.1. Apparatus

The Home Media Center is developed at TAUCHI in TÄPLÄ project (TÄPLÄ). NFC user interface was implemented by Intelligent Systems Group at University of Oulu. The Home Media Center system used in laboratory tests constructs of PC, digital TV, S60 phone (speech UI), S40 NFC enabled phone (NFC UI) and a tablet with RFID tags (Figure 11). The server software runs under Windows XP. The Home Media Center application is written in C# and Java, and it uses Piccolo graphics toolkit (Bederson & Grosjean, 2008). (Turunen et al. 2009b)

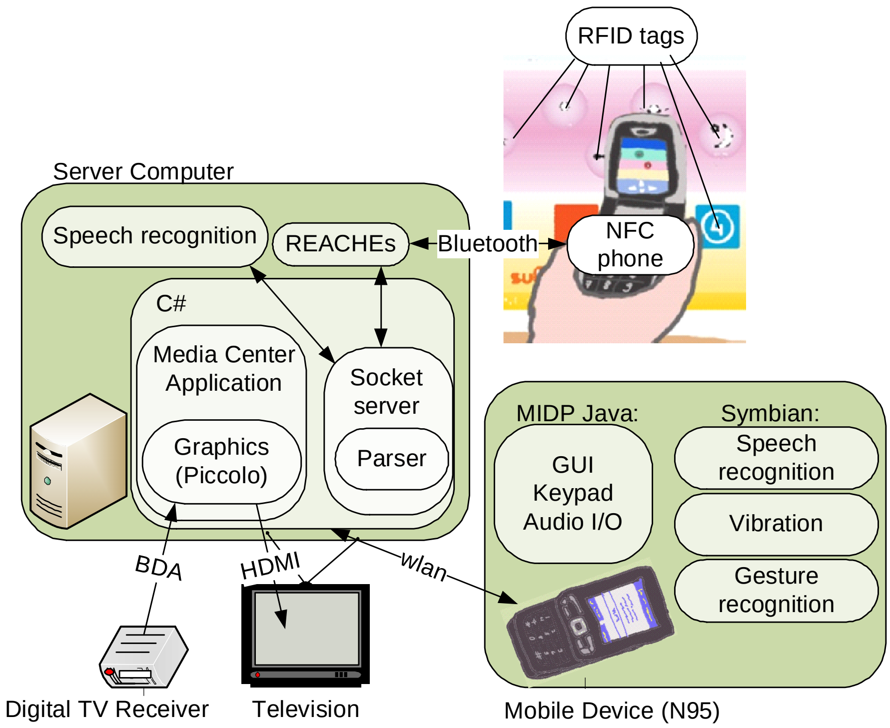

Figure 11 Home Media Center architecture with mobile devices. (Turunen et al. 2009b)

Input speech interaction is handled with the mobile devices native Symbian applications: gesture recognizer, speech recognizer and haptic feedback controller. Application logic, key input, and mobile phone display control are controlled with MIDP 2.0 applications (Oracle).

For NFC UI we used Nokia 6131 NFC enabled mobile phone. Application logic, RFID reader and phone display are controlled with MIDP 2.0 applications (Oracle). RFID tag store command information in NDEF format, which is conformable to NFC Forum specification (NFC Forum b). Intermediate proxy server REACHEs (Riekki et al. 2008) receives the tag information via Bluetooth. REACHEs processes the request and forwards it to the Home Media Center server. (Turunen et al. 2009b)

5.3.2. **The Home Media Center Graphical User Interface**

The media centre GUI consists of several screens, for different multimedia content such as photos and music. In the laboratory tests we used only TV's EPG (Figure 12). EPG consists of a grid. Columns describe different TV channels and rows describe time slots. Each program has its own cell. Different colours of the cells describe in what category program belongs to. Programs are divided to six categories: sports, movies, documents, children programs and news. (Turunen et al. 2009b)

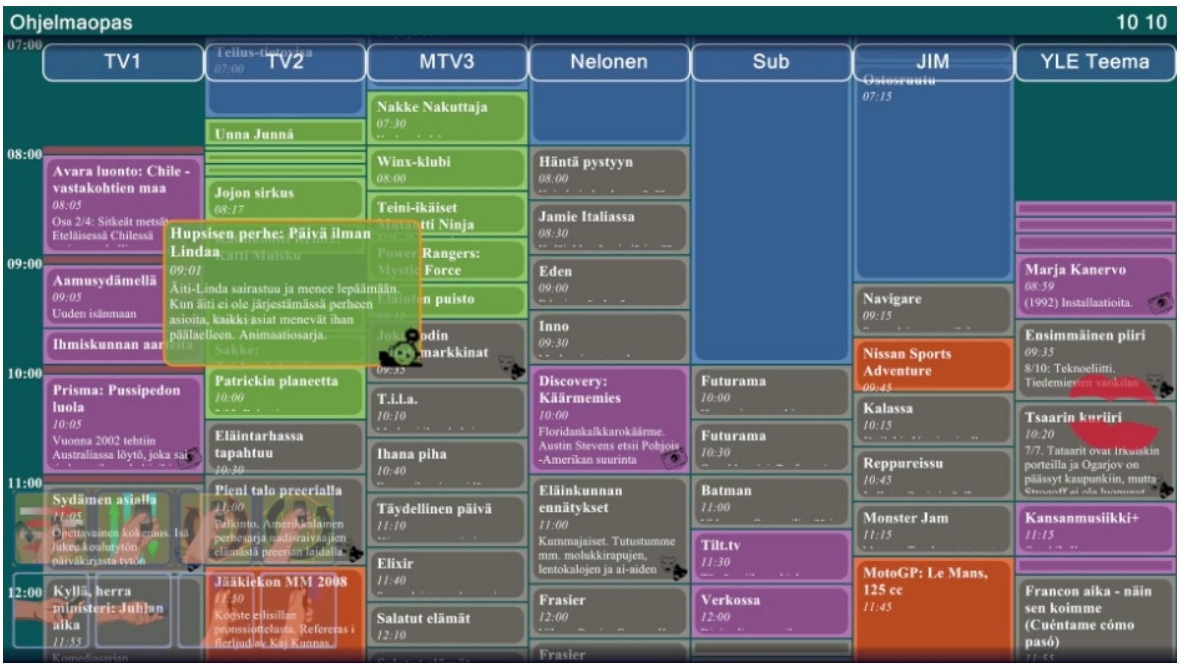

Figure 12 Media Center EPG

Lips on the right side of the screen (Figure 12), give users feedback of when a speech command is activated. There is also hints for the user for what is the current mode based on the mobile phones posture (left lower corner in the (Figure 13). Active program is highlighted and its cell enlarges. It is possible to zoom from weekly overviews to detailed information of selected program. (Turunen et al. 2009b)

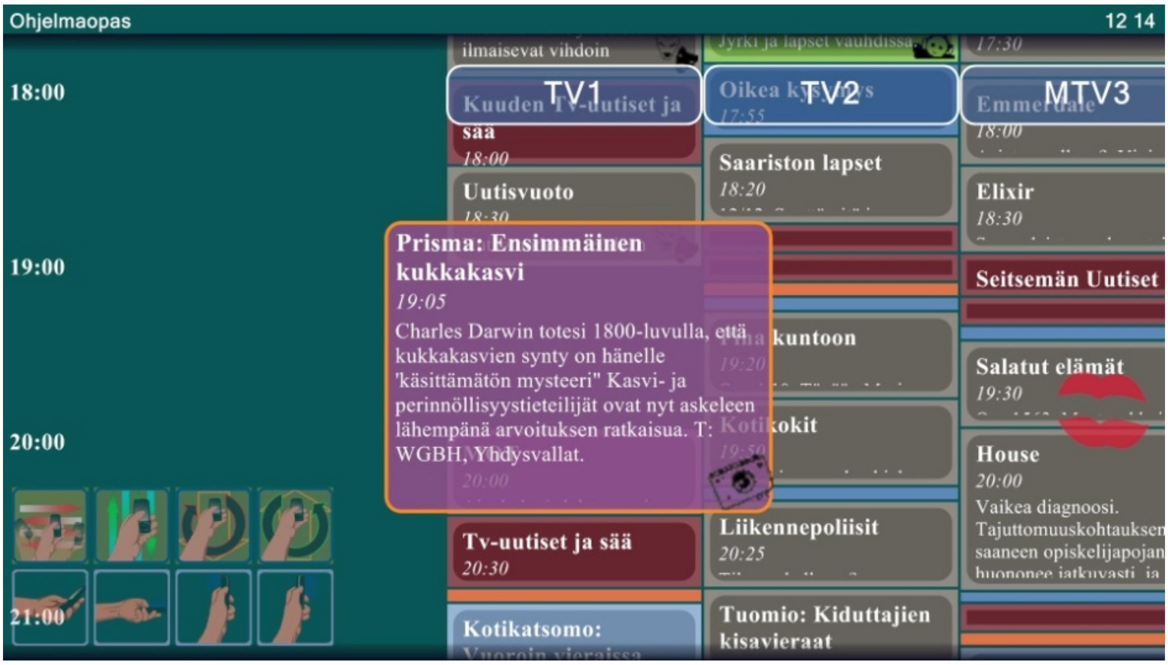

Figure 13 Media center EPG zoomed in.

The mobile phone applications give users feedback on the mobile phone display. Display shows the latest user input and provides feedback on the speech, gesture and touch inputs as well as error messages.

5.3.3. Speech and Gesture User Interface

Speech and gesture user interface input consists of mode selection with gestures and speech commands. In addition, it is possible to navigate in the EPG with mobile phone's direction buttons and select the speech command mode pressing the push to talk button below the mobile phone display. (Turunen et al. 2009b)

There are three different modes depending on the orientation of the mobile phone. When user raises the phone to vertical/up orientation, speech commands are activated (Figure 14). This is an analogy with speaking to a microphone. When user lowers the phone to the vertical/down orientation, speech command is sent to the Media Center server and phone is in the basic mode in which user can navigate in EPG and give voice commands pressing push-to-talk button. Third mode is the zoom mode (Figure 15). When phone is on its side, it is in the zoom mode. In this mode user can zoom in and out with phones up and down direction buttons.(Turunen et al. 2009b)

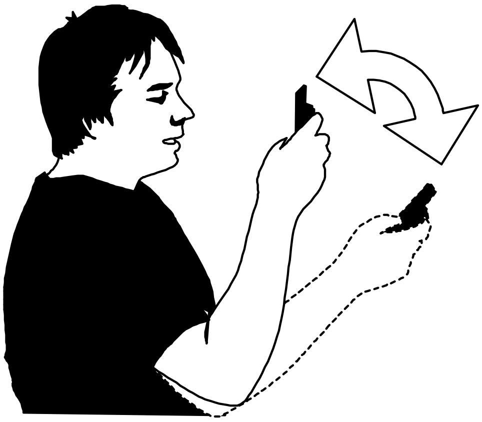

Figure 14 Raise to talk gesture. (figure by courtesy of TAUCHI)

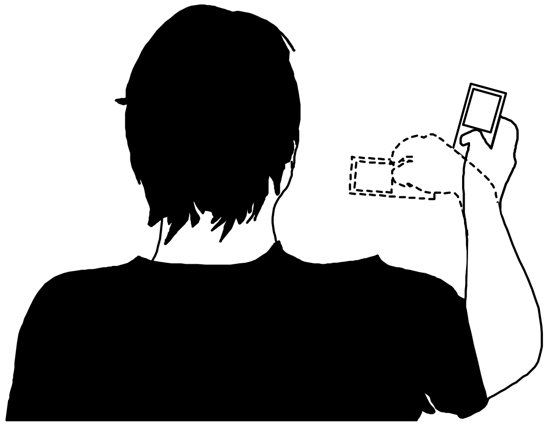

Figure 15 Zoom mode. (figure by courtesy of TAUCHI)

With voice commands user can also navigate in the EPG. Few examples of navigation commands: "Thursday", "Next day", "Show twenty o'clock", "Go to channel four" and "Today". It is also possible to set the recording and highlight certain categories. "Show documents" highlights all the documents. (Turunen et al. 2009b)

Grammar of the Media Center is rather small because voice recognition accuracy is dependent on the size of the language model. Grammar for the EPG contains approximately 110 words. Small vocabulary can be also problematic because amount of out-of-vocabulary (VOC) words is high. There for, it is crucial to give users enough guidance about the commands. In the EPG, it is possible to give voice command "Help" and list of the commands will show up on the television screen. (Turunen et al. 2009b)

5.3.4. NFC User Interface

NFC user interface consists of mobile phone and tablet (Figure 16) with RFID tags. Tablet was built especially for these tests. It is an A3-size-cardboard covered with A3 paper with icons describing commands stored in tags. RFID tags are place between the paper and the cardboard.

Figure 16 NFC User Interface Tablet

Tablet has five different areas. Icons on the green area left side of the tablet are for general commands. The three upper most icons are for moving between *EPG*, *TV* and *Recordings*. Three icons below describe recorder commands: *play, record* and *stop/cancel*. The three icons in the left lower corner of the tablet are for zooming between three different levels. These commands are all sent to the Media Center server immediately when the phone has read the command information from the tag.

White area in the right upper corner has *OK* and *Clear all touches* icons. *OK* command is used to send higher-level commands to Media Center server and *Clear all touches* is used to clear commands from the mobile phone if user has for example touched a wrong tag. Green area on the right lower corner has icons for *next day*, *previous day* and *today* commands. These commands are all sent to Media Center immediately.

Centre of the tablet has three different areas. Commands on the blue area describe program categories. Red area is reserved for commands for the time of the day: *morning*, *day*, *evening* and *night*. On the yellow background, there are tags for TV channels presented with TV channel logos, familiar to users.

User can compose higher-level commands with three areas in the centre of the tablet. User can for example first touch the *documents* tag, then the *morning* tag and finally choose a TV channel by touching a TV channel tag. After touching these tags, user touches *OK* tag or presses the selection button on the mobile phone and the command is sent to Media Center. In this case, focus of the EPG would move to morning on the channel two and all the documents are highlighted.

As with speech and gesture UI, user can navigate in EPG with mobile phones direction buttons. Left button below the display is for clearing the touches and the right button exits the application. Application can be started by simply touching any tag.

5.4. Methodology

This section describes the applied methodology. Methodology and test procedure was tested with three pilot tests. Some technical problems were discovered in the pilot tests and fixed before actual tests. I also phrased few tasks based on the feedback from the pilot tests.

5.4.1. The Implemented SUXES Evaluation Method

We used modified SUXES method in our laboratory tests. Main difference between SUXES method presented earlier, were in the metrics used in the study that included also hedonic aspects of user experience and presence of the test moderator. Contrary to previous studies, tasks were given by the moderator – not the automated web wizard.

Experiment consisted of following stages. CPU marks the phases that were done in the laboratory side-room with computer:

1. Background questionnaire (CPU)
2. Introduction to an UI (CPU)
3. Pre-test expectations questionnaire of an UI (CPU)
4. Test with an UI
5. Post-test user experience questionnaire of an UI (CPU)
6. Interview about the experiences and future use possibilities for physical touch UI

The experiment was carried out in IHTE usability laboratory, as illustrated in Figure 8. Subjects filled in the questionnaires (steps 1, 3, and 5) and watched the introduction videos (step 2) by oneself in a calm atmosphere at laboratories side-room. Questionnaires were simple web-forms that were familiar to fill in for the subjects. Actual tests (step 4) were held in a home-like setup in other room of the laboratory. Phases 2-5 were conducted for both UIs. Order of the UIs was counterbalanced. Thus 50% of users used the physical touch UI first and 50% of users used the speech UI first.

Figure 17 : Participant performing a task with NFC user interface.

After watching the introduction videos, participants were asked to fill in a questionnaire concerning their expectations about the system (step 3). They were asked to mark both an acceptable and desirable level on each statement. Statements for pre-test expectation and post-test experiences were as follows.

1. Possibilities of the X interaction are visible
2. Using the X interaction is easy
3. X interaction is suitable for this purpose
4. Using the X interaction combines me with other people
5. X interaction is innovative
6. It is fast to use X interaction
7. It is fascinating to use X interaction
8. It is stylish to use X interaction
9. X interaction is practical
10. Using X interaction is acceptable by other people
11. X interaction is useful
12. It is simple to use X interaction
13. X interaction is robust

After that, each participant was then given 4-5 exercise tasks depending on which UI was used and 11 evaluation tasks (Table 9) with the EPG prototype. The order of the participants used UI's was counterbalanced. The order of the task presentation was the same for each participant. The tasks reflect typical usage scenarios, e.g. getting information from certain program such as director of the film, highlighting program categories, recording a program and changing channels in the electronic program guide.

Table 9 Tasks given to participants in laboratory tests.

Touch UI		Speech & gesture UI
T1	What is the name of the current program on channel YLE Teema?	What is the name of the curren program on channe Four?
T2	Whhostarres in the film that comes form SUB TV tomorrow night?	Where is the film coming from YLE teema tomorrow evening located?
T3	Which channels show sports programs tomorrow?	Which channels show children's programs tomorrow?
T4	Set recording for the Prisma documentary that comes out Sunday morning	Set recording for the Prisma documentary that comes out Mondey evening
T5	Which channel has the next news?	Which channel has the next news?
T6	Which icon and color describes children's programs?	Which icon and color describes sports programs?
T7	Remove the recording from the Sunday documentary	Remove the recording from the Monday documentary
T8	What series does SUB TV show after midnight on Saturday night?	What series does Channel Four show before noon on Monday morning?
T9	What is the category of the program that shows on MTV3 tonight at nine o'clock?	What is the category of the program that shows on MTV3 tonight at eight o'clock?
T10	Set recording for the Thursday's Pikku Kakkonen	Set recording for the Friday's Pikku Kakkonen

After completing the tasks, they filled in a questionnaire consisting of the same statements they were asked in the pre-test questionnaire (step 5). This time the participants gave only one value to indicate their perceived experience.

In addition to evaluation with SUXES questionnaires, subjects evaluated overall UX and user acceptance with three questions on a scale 1-7. Questions measured overall UX and user acceptance of the different interaction styles. These questions were presented in both pre-test and post-test questionnaires. These questions were:

- I would use this interaction style in future.
- I would recommend this interaction style to my friend.
- This interaction style is suitable for me.

In step 6, an interview was conducted to get feedback about the evaluation method and to gather general feelings of interaction methods. We also asked, if it is suitable to use animations as an introduction stimulus to an application and collected ideas for domains and applications that would be suitable for touch-based interaction.

5.4.2. Animations Used to Introduce the Home Media Center to the Participants

In the second step, participants were introduced to the user interfaces by short animated introductions (Figure 18). Animation for introducing speech & gesture user interface was 1min 14sec long and the animation used to introduce the NFC user interface lasted 2min 30sec. Our goal was to give users basic understanding of different interaction styles, but not too precise instructions of use. Thus, users concentrated evaluating the interaction styles, instead of focusing on details and specific features of the UIs when they filled the pre-test expectations questionnaire.

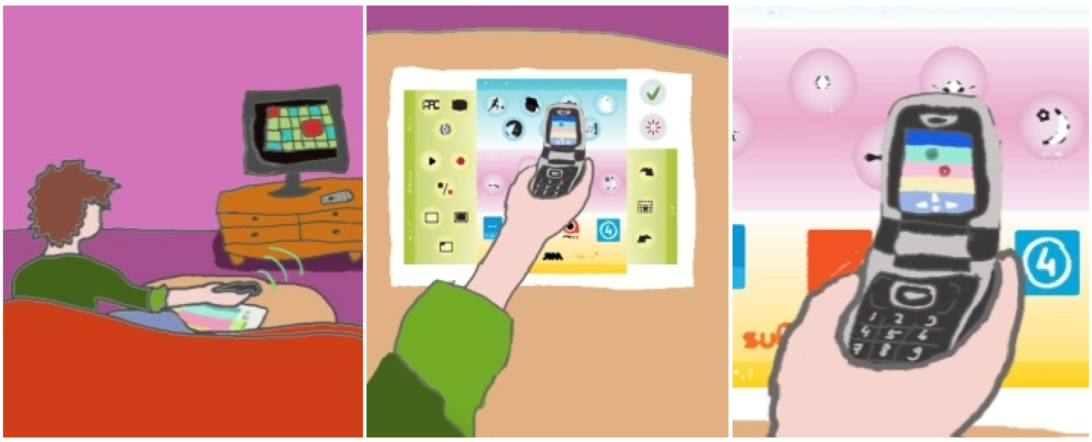

Figure 18 Screenshots from the animated introductions. Figures by artist Kanerva Niemelä.

Using same material with every participant assured that every user had exactly same knowledge of the UIs before the pre-test expectations questionnaire (step 3). Animated instructions were made in co-operation with an artist who made the sketches of user interfaces and usage situations. Sketches were animated with simple Power Point slideshow animation effects. Slideshow was then recorded with screen capture software and spoken instructions were added to the movie.

5.4.3. Participants

Eleven males and nine females participated in the study. They received two movie tickets or similar complimentary gift as compensation for participating in the study. Participants' age ranged from 19 years to 59 years with a mean of 27.7 years (SD 9.1). We inquired if the participants had previous experiences with the phones used in the tests and with smart phones in general. Fifteen out of twenty participants had used smart phones previously. Despite one researcher and one unemployed participant, the participants were students from Tampere University of Technology and University of Tampere. Participants were given explanations of different interaction methods in order to clarify for example what are the RFID applications near the users (public transport smart card, access card to university).

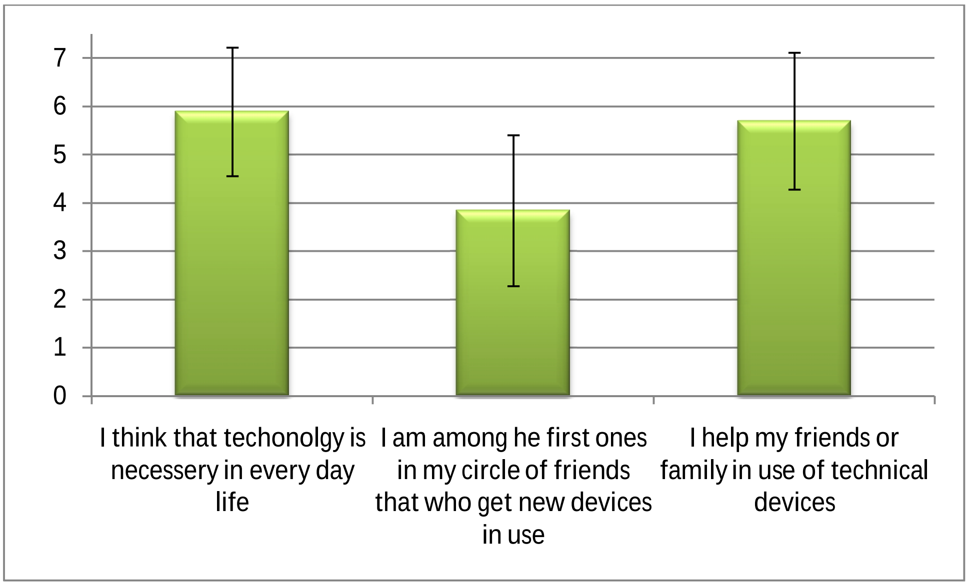

Figure 19 Technical orientation of the laboratory study session participants

Participants were presented three statements on a scale of 0-7, seven being "I agree totally" and zero "I totally disagree", presented in Figure 19 . Technology was seen very important by most of the users (mean 5.9, SD 1.3), participants also helped their friends or family relatively much (mean 5.7, SD 1.4). Participants were more neutral in their answers for the third question about when they get new devices compared to their circle of friends and their answers varied more in this statement (mean 3.9, SD 1.7).

Participants' use frequency of studied interaction methods was also asked (Figure 20).

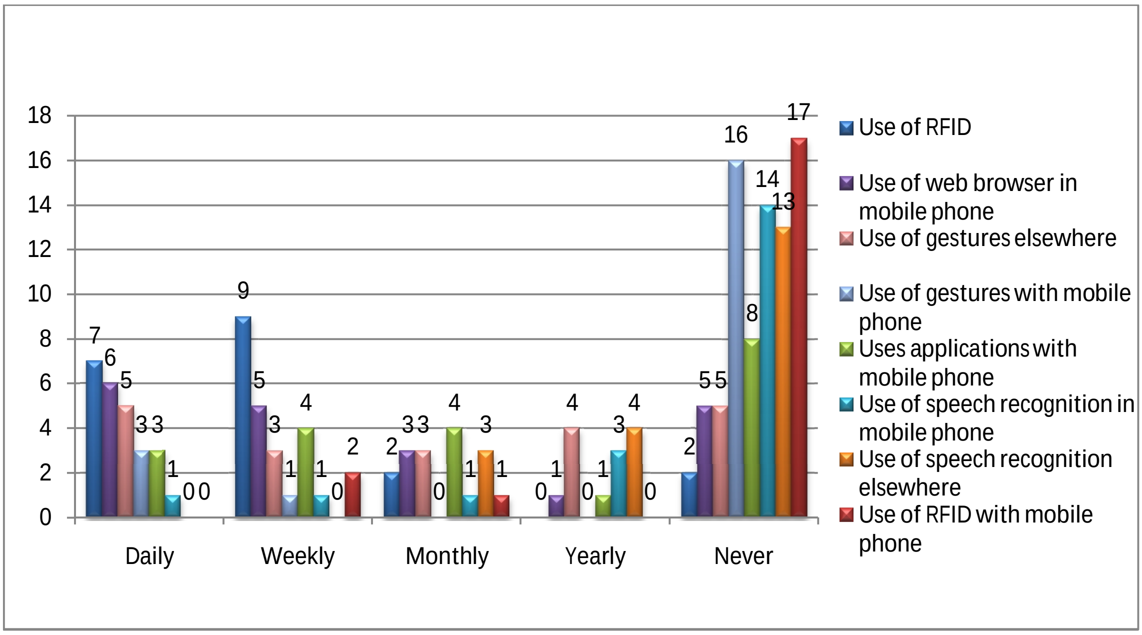

Figure 20 Participants' background with the studied interaction methods

Sixteen out of twenty participants used RFID technology daily or weekly and only two of the participants had never used RFID applications. Using internet with mobile phone was also quite common. Half of the participants used web browser on their mobile phones daily or weekly. On the other hand, five of the participants had never used web browser with a mobile phone. These participants had no experience with smart phones. Eleven of the participants used installed applications with their mobile phone at least monthly but eight participants had never used installed applications. Only few participants used gestures (four participants) and speech recognition (three participants) frequently (daily, weekly, and monthly). Two participants used RFID with their mobile phone weekly and one participant used RFID with mobile phone monthly. Other participants had never used RFID with mobile phone.

5.5. Analysis

5.5.1. Metrics Based on Attracdiff 2

In order to measure hedonic quality attributes of user experience I derived metrics (Table 10) from Hassenzahl et al. (2003). I translated attributes from German and English to Finnish. This was challenging because there is no direct counterpart in Finnish for every attribute.

Table 10 Bipolar Verbal Anchors and translation in German and Finnish

Attri bute	Original anchors		Translated German anchors		Translated Finnish anchors	
HQI attributes						
HQI1	Isolierend	Verbindend	Isolating	Integrating	Eristävä	Yhdistävä
HQI5	Ausgrenzend	Einbeziehend	Non-inclusive	Inclusive	Pois sulkeva	Mukaan ottava
HQI6	Trennt mich von Leuten	Bringt mich den Leuten näher	Takes me distant from people	Brings me closer to people	Vie minut kauemmaksi ihmisistä	Tuo minut lähelle ihmisiä
HQI2	Laienhaft	Fach-männisch	Amateurish	Professional	Ammattimainen	Harrastelija-mainen
HQI3	Stillos	Stilvoll	Gaudy	Classy	Mauton	Tyylikäs
HQI4	Minderwetig	Wertvoll	Cheap	Valuable	Arvoton	Kallisarvoinen
HQI7	Nicht vorzeigbar	Vorzeigbar	Unpresentable	Presentable	Epäedustava	Edustava
HQS attributes						
HQS 1	Konventio-nell	Originell	Typical	Original	Perinteinen	Kekseliäs
HQS 4	Konservativ	Innovativ	Conservative	Innovative	Konservatiivinen	Innova-tiivinen
HQS 7	Her-kömmlich	Neuartig	Commonplace	New	Tavanomainen	Uudenlainen
HQS 2	Phantasielos	Kreativ	Standard	Creative	Mielikuvitukseton	Luova
HQS 3	Vorsichtig	Mutig	Cautious	Courageous	Varovainen	Rohkea
HQS 5	Lahm	Fesselnd	Lame	Exciting	Tylsä	Kiehtova
HQS 6	Harmlos	Heraus-fordernd	Easy	Challenging	Helppo	Haastava
PQ attributes						
PQ1	Technisch	Menschlich	Technical	Human	Tekninen	Inhimillinen
PQ2	Kompliziert	Einfach	Complicated	Simple	Monimutkainen	Yksin-kertainen
PQ4	Umständlich	Direkt	Cumbersome	Direct	Vaikeaselkoinen	Suora-viivainen
PQ6	Verwirrend	Ubersichtlich	Confusing	Clear	Sekava	Selkeä
PQ3	Unpraktisch	Praktisch	Impractical	Practical	Epä-käytännöllinen	Käytännölli-nen
PQ5	Unberechen-bar	Voraussagbar	Unpredictable	Predictable	Arvaamaton	Ennustettava
PQ7	Widerspenstig	Handhabbar	Unruly	Manageable	Hallitsematon	Hallittava

After translation I grouped attributes further to find two groups of similar attributes in every group of qualities. For HQI and HQS organizing attributes to two groups was straight forward. I divided HQI attributes into two groups: social presence (HQI1, HQI5 and HQI6) and social identity (HQI2, HQI3, HQI4 and HQI7). HQS attributes were divided to novelty (HQS1, HQS4 and HQS7). For pragmatic attributes I identified three groups: nature of product (PQ1), efficiency (PQ2, PQ4 and PQ6) and effectiveness (PQ3, PQ5 and PQ7).

Rearranging the attributes was done in order to keep the questionnaires used in laboratory tests as light as possible. Because I used SUXES method that uses statements for evaluation of user experience, bipolar semantic scale was not suitable. I derived one statement from each reorganized group of quality attributes (Table 11).

Table 11 Categories and statements.

Category	Statement 1	Statement 2
HQI	...is acceptable by others	...is classy
HQS	...is exciting to use	...is Innovative way to work
PQ	...is practical to use	...is simple to use
Efficiency	...is easy to learn	...is fast to use
Effectiveness	...is robust to use	...is useful to use
DIEM	Possibilities of this UI are visible	This interaction style fits this context

PQ group *nature of product* (PQ1) I excluded from questionnaire, because evaluating whether the interaction or UI is *human* was seen difficult. From HQI I originally derived three statements but third statement "*This interaction style brings me closer to other people*" was seen difficult to understand. Thus, it was excluded from analysis.

There are also statements for "traditional" usability metrics, efficiency and effectiveness, that have been used in previous studies. These attributes were included so it is possible to compare results with previous studies. Last category, concerning especially attributes important for interoperability of devices, was taken from DIEM UX framework draft (established inside the DIEM project).

5.5.2. Data Analysis with SUXES Method

As a result, from expectations and experience questionnaires of the SUXES method it is possible to compare whether the participants' expectations were met (Figure 21). Median values of the accepted and desired level for a statement form a zone of tolerance (ZOT). If perceived experience is inside the ZOT it is possible to make a conclusion that the participants' expectations were met quite well. (Turunen et al. 2009a)

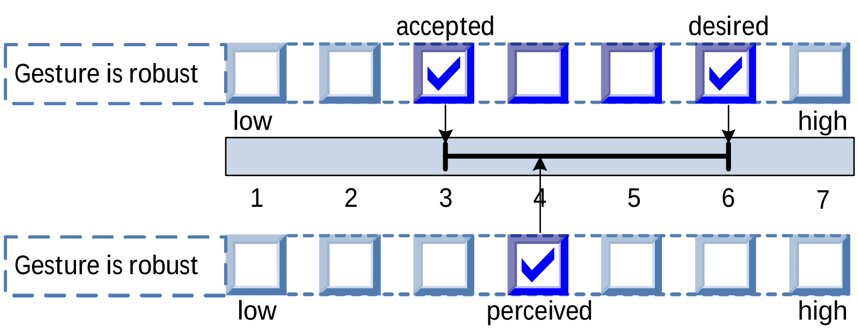

Figure 21 Interpreting expectations and perceptions of user experience. (Turunen et al. 2009a)

It is also possible to calculate Measure of Service Superiority (MSS) and the Measure of Service Adequacy (MSA) based on the gaps between three collected values of the same statement. MSS is the difference between the perceived experience and desired level. Thus, when MSS is negative the perceived experience exceeded the desired level and quality under examination is perceived as superior compared with expectations. MSA is the difference between the perceived experience and accepted value. Thus, when the MSA is negative the perceived experience was not even adequate compared with expectations. (Turunen et al. 2009a) In the example above (Figure 21), MSS is 4-6=-2 and MSA is 4-3=1.

5.5.3. Traditional Usability Metrics

Usability metrics collected in laboratory tests were time-on-task, task success, learnability and usability issues that were gathered with observation and in post-test interviews. During the task performance, I observed usability issues. I reported the usability issues straight to the implementers. Thus, I did not write a specific usability report or defined the severity of found issues. There were also some technical issues, so called bugs, found that I reported to implementers.

I calculated means of the time-on-task and compared the results of touch-based interaction and speech & gesture interaction. In order to exclude the effect of high variation in the means I also present medians for time-on-task. Learnability of the user interfaces was measured by comparing task times for two similar tasks.

5.6. Results

5.6.1. User Experience of Different Interaction Methods

Figure 10 visualizes the main results for each question and input method. It shows the Zones of Tolerance across the dimensions using values for the acceptable level (lower bound), desired level (upper bound), and perceived level (black circles).

ZOT for traditional usability metrics, *efficiency, effectiveness* and *PQ*, have higher means than for hedonic qualities and DIEM attributes. This can be interpreted so that participants had higher demands for acceptability and desired level for traditional usability metrics, in other words for usability and utility.

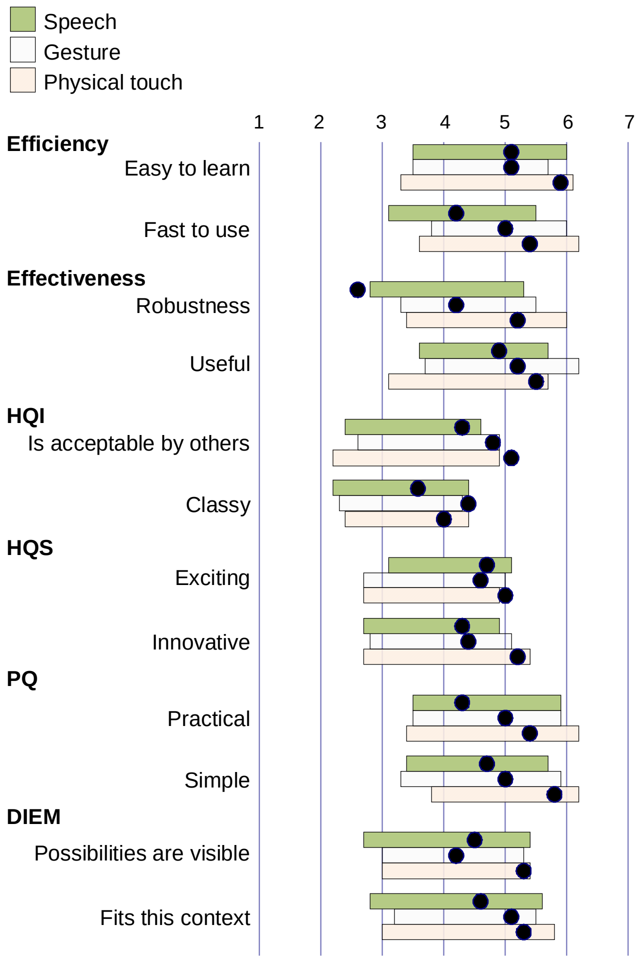

Figure 22 Summary of results from expectations and experience questionnaires. (N=20)

I formed sum variables for overall UX from means of the answers to questions about over all user experience and acceptance (Table 12). Over all pre-test expectations were quite similar, although users were optimistic for gesture and physical touch compared to speech. In the case of speech and gesture, these were not met completely, indicated by the negative values. In the case of physical touch, user experience was slightly better compared to pre-test expectations.

Table 12 Overall UX and user acceptance variables

Interaction style	Pre-test	Post-test	Gap
Speech	4.7	4.5	-0.2
Gesture	5.4	5.3	-0.1
Physical touch	5.4	5.5	0.1

Table 13 presents means of the participants' evaluation of pre-test expectations and perceived experience of measured metrics. There is also the zone of tolerance presented for every metric. Means of the metrics (yellow), show that pre-test expectations towards different modalities were quite similar. Acceptable level (light pink) varies from 3.0 to

3.1 and desired level (violet) varies from 5.3 to 5.6. Zone of tolerance for *gesture* (2.3) is somewhat smaller than for *speech* (2.4) and *touch* (2.5). ZOT of metrics *innovative*, *practical* and *acceptable by others* for *touch* is clearly larger. Notable is that perceived UX (orange) of *speech* (4.3) is much below the perceived UX for *gesture* (5.4) and for *touch* (5.6).

Table 13 Means of the expectations, perceived user experience and ZOT. (N=20)

Metric	SPEECH				GESTURE				TOUCH			
Hedonic Quality Stimulation	Min	Max	UX	ZOT	Min	Max	UX	ZOT	Min	Max	UX	ZOT
Is Exciting	3,1	5,1	4,7	2,0	2,7	5,0	4,6	2,3	2,7	4,9	5,0	2,3
Is Innovative	2,7	4,9	4,3	2,2	2,8	5,1	4,4	2,3	2,7	5,4	5,2	2,7
Pragmatic Quality												
Is practical	3,5	5,9	4,3	2,4	3,5	5,9	5,0	2,4	3,4	6,2	5,4	2,8
Is simple to use	3,4	5,7	4,7	2,3	3,3	5,9	5,0	2,6	3,8	6,2	5,8	2,4
Hedonic Quality Identification												
Is acceptable by others	2,4	4,6	4,3	2,3	2,6	4,9	4,8	2,3	2,2	4,9	5,1	2,7
Is classy	2,2	4,4	3,6	2,2	2,3	4,3	4,4	2,0	2,4	4,4	4,0	2,0
Efficiency												
Easy to learn	3,5	6,0	5,1	2,6	3,5	5,7	5,1	2,2	3,3	6,1	5,9	2,8
Fast to use	3,1	5,5	4,2	2,4	3,8	6,0	5,0	2,3	3,6	6,2	5,4	2,6
Effectiveness												
Is robust to use	2,8	5,3	2,6	2,6	3,3	5,5	4,2	2,3	3,4	6,0	5,2	2,6
Is useful to use	3,6	5,7	4,9	2,2	3,7	6,2	5,2	2,5	3,1	5,7	5,5	2,6
DIEM attributes												
Possibilities are visible	2,7	5,4	4,5	2,7	3,0	5,3	4,2	2,3	3,0	5,4	5,3	2,4
Fits this context	2,8	5,6	4,6	2,8	3,2	5,5	5,1	2,4	3,0	5,8	5,3	2,8
Mean	3,0	5,3	4,3	2,4	3,1	5,4	4,7	2,3	3,0	5,6	5,2	2,5

Touch-based interaction has the best evaluation. It was seen exciting (*MSS*=0.0) and it has clear affordances because for *possibilities are visible* –metric *MSS*=0.0. Touch-based interaction is evaluated to be easy to learn (*MSS*=*-0.*1) and rather innovative (*MSS*=*-0.*3) and useful (*MSS* =*-0.*3). All evaluations of *MSS* for touch-based interaction were under 1.0. Thus, the expectations were met quite well. Only metric where touch did not get the best evaluation is *is classy* –metric. Gesture and touch are thought to fit the context just as well (*MSS*=*-0.*5).

Table 14 presents the measures of service superiority (MSS) and service acceptability (MSA) for every modality. Three values (yellow) are off the zone of tolerance. *MSS* of *acceptable by others* –metric for *touch* is -0.2, which means that perceived experience exceeds the desired level. Thus, touch-based interaction is thought to be acceptable by others. Gestures is seen as classy because *MSS* of *is classy* –metric is 0.1. *MSA* of *is robust to use* –metric for *speech* is -0.2. Thus, speech interaction was seen unreliable. One reason for this is rather poor speech recognition rates.

Touch-based interaction has the best evaluation. It was seen exciting (*MSS*=0.0) and it has clear affordances because for *possibilities are visible* –metric *MSS*=0.0. Touch-based interaction is evaluated to be easy to learn (*MSS*=-0.1) and rather innovative (*MSS*=-0.3) and useful (*MSS* =-0.3). All evaluations of *MSS* for touch-based interaction were under 1.0. Thus, the expectations were met quite well. Only metric where touch did not get the best evaluation is *is classy* –metric. Gesture and touch are thought to fit the context just as well (*MSS*=-0.5).

Table 14 Means of the MSS and MSA. (N=20)

Metric	*SPEECH*		*GESTURE*		*TOUCH*	
Hedonic Quality Identification	MSS	MSA	MSS	MSA	MSS	MSA
Is acceptable by others	-0.4	1.9	0.0	2.2	0.2	2.9
Is classy	-0.9	1.4	0.1	2.1	-0.5	1.6
Hedonic Quality Stimulation						
Is Exciting	-0.4	1.6	-0.5	1.9	0.0	2.3
Is Innovative	-0.6	1.6	-0.7	1.6	-0.3	2.5
Pragmatic Quality						
Is practical	-1.6	0.9	-1.0	1.5	-0.8	2.1
Is simple to use	-1.0	1.3	-0.9	1.7	-0.4	2.1
Efficiency						
Easy to learn	-1.0	1.6	-0.6	1.6	-0.1	2.6
Fast to use	-1.3	1.1	-1.1	1.2	-0.8	1.8
Effectiveness						
Is robust to use	-2.7	-0.2	-1.3	1.0	-0.8	1.8
Is useful to use	-0.8	1.4	-1.0	1.5	-0.3	2.4
DIEM attributes						
Possibilities are visible	-0.9	1.9	-1.1	1.3	0.0	2.4
Fits this context	-1.0	1.8	-0.5	1.9	-0.5	2.3
Mean	-1.0	1.3	-0.7	1.4	-0.3	2.2

Speech is seen slightly more exciting, innovative and useful than gestures. The evaluation for affordances of speech (*MSS*=-0.9) is also slightly better than the evaluation for affordances of gestures (*MSS*=-1.1). In other metrics, *gestures* are seen slightly better than *speech*. In summary, the means of MSS and MSA for different modalities show that *touch-based interaction* (*MSS*=-0.4, *MSA=2.2)* overcomes *speech* (*MSS*=-1.3, *MSA*=1.3*)* and *gesture* (*MSS*=-0.9, *MSA*=1.4*)* interactions.

5.6.2. **Usability metrics**

Usability issues

Task success was high as only in ten tasks out of two-hundred I had to assist the participant to finish the task. Usability issues I reported were for example speech commands that would fit user's mental model better, slowness of touching the same tag repeatedly while moving between weekdays and the threshold of the accelerometer for gestures when changing between modes. The most severe usability issue was the activation of the speech commands. Several users started to speak too early and this had significant effect on the speech recognition accuracy.

Objective usability metrics

Time-on-task results with standard deviations are presented in Figure 23. Percentage describes the time used with touch-based interaction compared with the time used with speech & gesture user interface. Touch-based interaction appeared to be more efficient except in the task 3 in which the mean of task-on-time for touch-based interaction was 100.7 % compared with the task-on-time the speech & gesture user interface. The task 3 required zooming out to count the number of programs in certain program category. Thus, using a gesture to activate zoom mode and zoom with mobile phone direction buttons was as efficient as the zooming with three zoom tags.

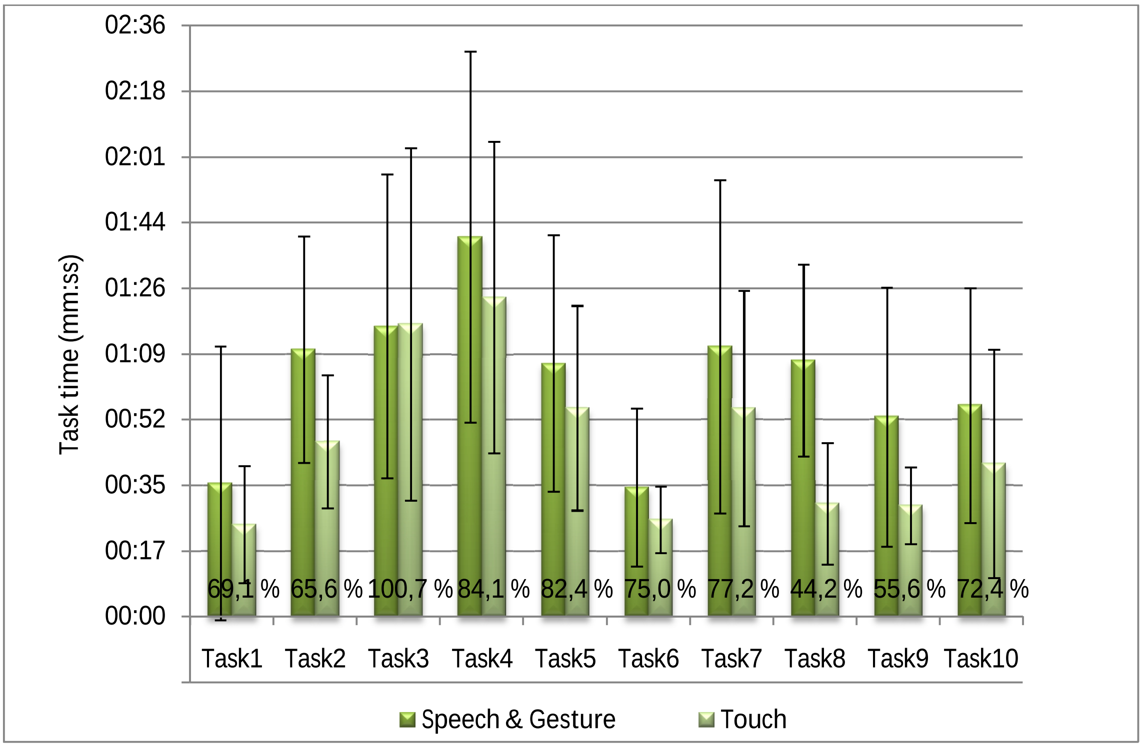

Figure 23 Means of the time-on-task. Error bars describe standard deviation. (N=20)

All together time-on-task for touch-based interaction was 72.7% of the time-on-task for the speech & gesture user interface. It is notable that the standard deviation for the speech & gesture interaction (34 seconds) is much greater than for the touch-based interaction (24 seconds). This can be explained with great differences on speech recognition accuracy between participants.

(Figure 24). The results do not differ very much from the means of the time-on-task. The mean of time-on-task for the touch-based interaction was 80.2% of the time-on-on task for the speech & gesture interaction.

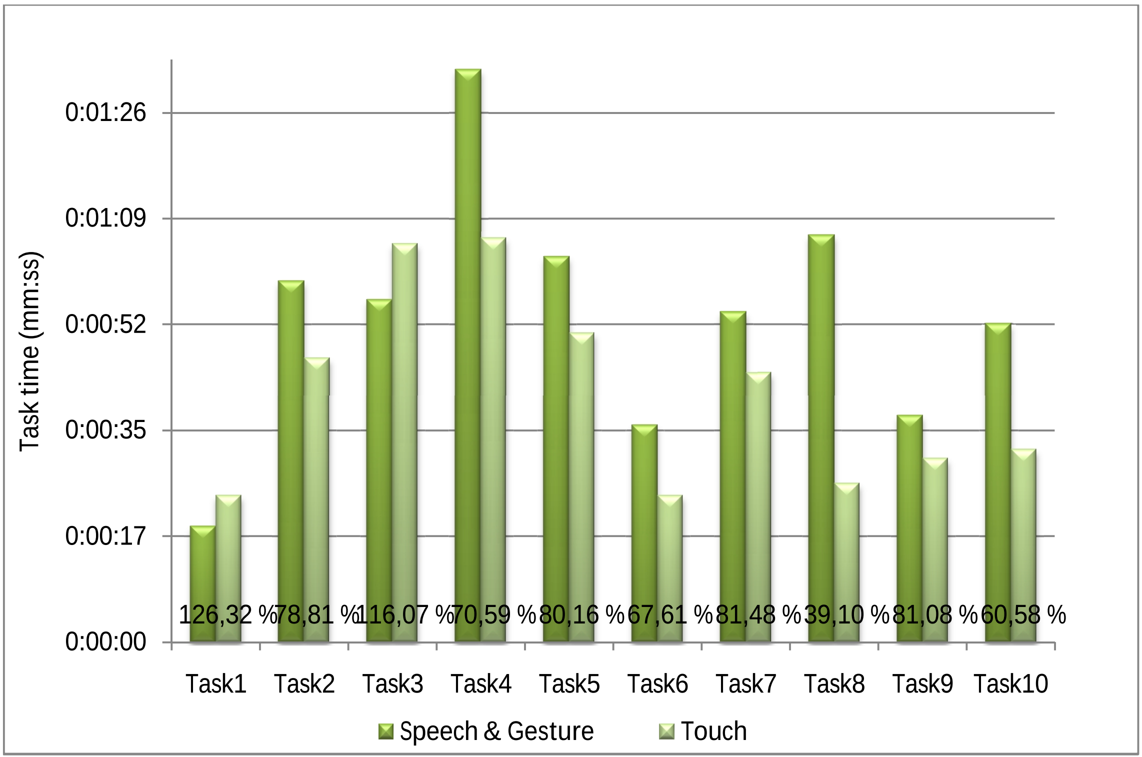

Figure 24 Medians of time-on-task. (N=20)

In addition to the task 3, the task 1 is also more efficient with speech & gesture than with touch-based interaction. The task 1 required zooming, in order to read the name of the current program on certain channel more easily. In this task, touch-based interaction was 26.3% slower than with speech & gesture interaction. Thus, for task 1 using a gesture to activate zoom mode and zoom with mobile phone direction buttons was more efficient as the zooming with three zoom tags.

Learnability of the user interfaces was measured by comparing task times for two similar tasks (task 4 & task 10). In these tasks, participants were asked to record a certain program. With speech & gesture user interface, task 10 was performed 44.4% faster than task 4 and with touch-based user interface task 10 was performed 52.3% faster than task 4.

5.6.3. **Speech Recognition Accuracy**

During the laboratory tests, it came obvious that speech recognition accuracy was not satisfactory for every participant. Thus, I evaluated speech recognition by counting correct commands, similar commands and out of vocabulary commands (OOV) (Table 15). Similar commands were for example commands that were missing a word. Number of commands given by the participant during the whole test varies very much between participants. Smallest number of commands is 31 and the highest number is 88 (mean 51.4, SD15.9).

Table 15 Number of sentences and commands.

Commands per participant	Mean	Min	Max	SD
Correct	35.6	17	74	14.0
Similar	7.3	2	22	5.0
Out of vocabulary	8.6	2	22	4.9
Number of commands	51.4	31	88	15.9

The number of OOV commands varies from 2 to 22 (mean 8.6, SD 4.9). Great variation is mainly due to large differences in speech recognition accuracy among the participants. For example, participant with maximum amount of 88 commands had the lowest speech recognition accuracy of 41.9% for correct commands (Figure 25).

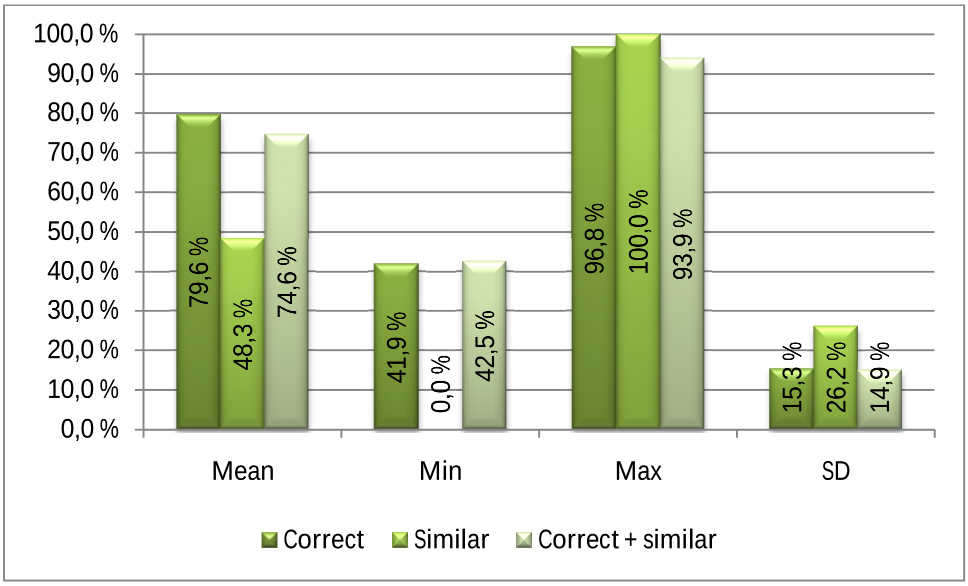

Figure 25 Speech recognition accuracy for correct and similar commands.

Speech recognition accuracy for correct commands is 79.6% and for commands included similar commands 74.6%. In case of similar commands, variation between the participants was high. The lowest speech recognition accuracy was 0% and the highest accuracy was 100% (SD 26.2%). The lowest speech recognition accuracy was 41.9% and the highest accuracy was 96.8% (SD15.3).

Main reason for low speech recognition accuracy was *the raise to talk gesture* used to activate the speech commands. In the videoanalysis of the tests that had the lowest speech recognition accuracy it was obvious that participants started to speak the command before the speech commands were activated. The large number of the OOV words caused low speech recognition results for the users that did not check the right comman beforehand.

5.7. **Summary**

All together twenty people participated the laboratory tests. Usability issues were gathered for further development of the usability of the Home Media Center. Objective metrics show that touch-based interaction was more efficient than speech & gesture. Touch-based interaction was also evaluated to have the best overall user experience and it scored the highest scores in almost every user experience attribute. Speech recognition accuracy was a disappointment. This explains some of the lower scores in the user experience attributes.

According to comments from participants in post-test interviews, questionnaires were seen easy and not too burdensome to answer. Using simple animations as an introductory material for first time use of a new application was appreciated. A participant compared animations with paper manuals:

> “*I never read manuals but this kind of instructions would be nice to have for other products as well*“.

6. STUDY 2: EXPLORING USER EXPERIENCE

This chapter describes the methodology and procedure used in two group sessions held at the Technical University of Tampere, as well as the results from the group sessions. In the first section, goals of the study are presented. The second section gives an insight to the theories and methods behind the methodology used in this study. In section 6.2, the used method is described in detail as well as participants and analysis methods. The section 6.3 presents the results of the study that are summarized in the last section of this chapter.

6.1. Goals of the Study

We arranged two group sessions in order to identify user experience elements of touch-based interaction with mobile phones. Goals of the study were as follows:

Goal 1: Identifying user experience elements of touch-based interaction with mobile phones
Goal 2: Creating novel use cases for touch-based interaction with mobile phones
Goal 3: Gathering experiences of *context walk* method used as a stimulus for group discussions and for collecting user experiences.

6.1.1. Group Session

Different kinds of group sessions have proved to be efficient in innovation. Cooper & Edgett (2008) studied 18 different innovation methods in order to find out which innovation methods are most popular and efficient. They divided innovation methods in to three categories: voice of customer (8 methods), open innovation approaches (6 methods), such as external idea contest, and other methods (four methods), such as patent mapping. The most interesting methods for UCD are voice of customer (VOC) methods listed below.(Cooper & Edgett 2008)

- Ethnographic research
- Customer visit teams
- Customer focus groups for problem detection
- Lead user analysis
- Customer or user design
- Customer brainstorming
- Customer advisory board or panel

- Community of enthusiasts

Cooper & Edgett (2008) conducted the study with 160 companies. They were interested in how efficient different methods were seen by the company management and how widely different methods are used. Figure 26 presents the magical ideation quadrant diagram. Effectiveness was rated on a scale 0-10 (y-axis) and x-axis describes the percentage of companies that use a method extensively. (Cooper & Edgett 2008)

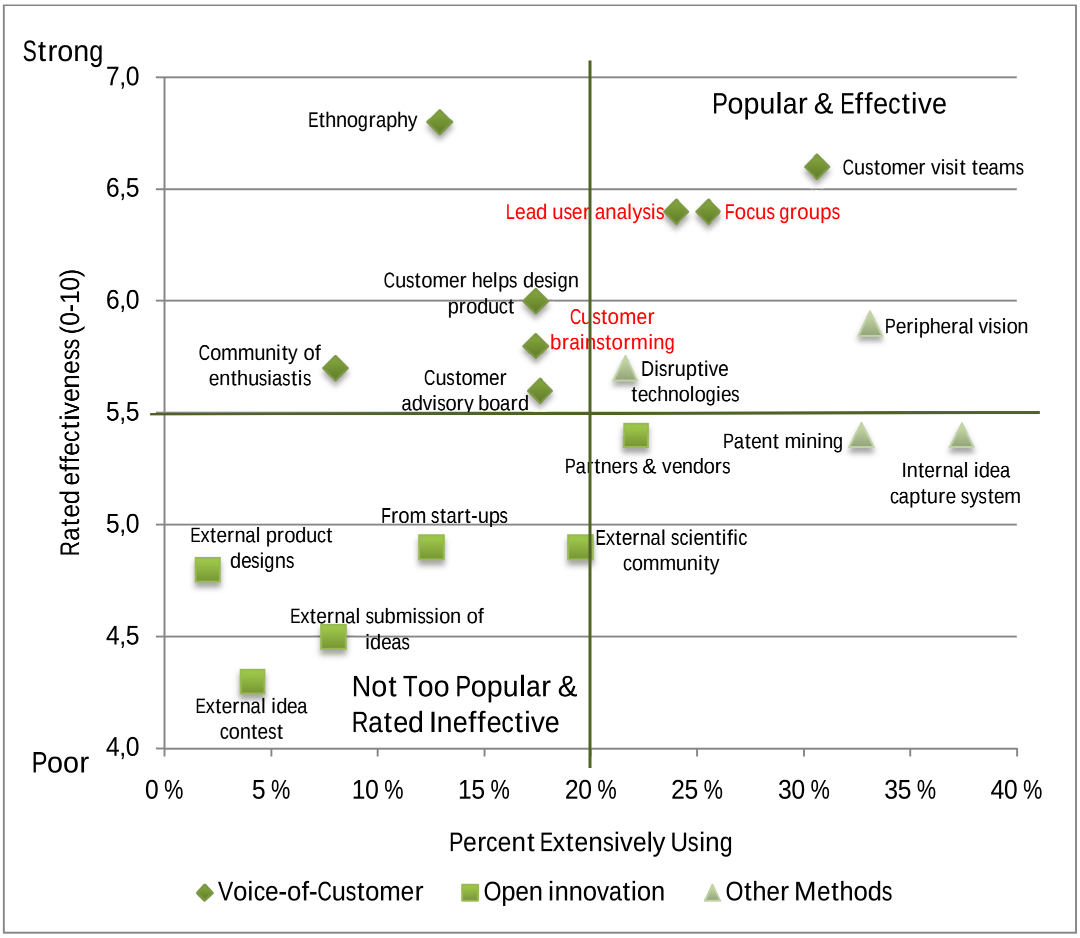

Figure 26 The Magic Ideation Quadrant

In general, *VOC* methods were seen the most effective methods and three of the most popular of top six methods were *VOC* methods. *Open innovation* methods are still relatively new and therefore not too popular. *Open innovation* methods were seen as ineffective. *Other methods* were widely used and seen relatively efficient. (Cooper & Edgett 2008)

Three VOC methods (marked red in Figure 26) that include group sessions were ranked relatively high in both popularity and effectiveness. *Focus groups* were used extensively by 25.5 percent of the companies with rate of 6.4 out of 10 in effectiveness. *Lead user analysis* was almost as popular with 24.0 percent and effectiveness score of 6.4 out of 10. *Customer brainstorming* was outside the *Popular and Effective* quadrant. However, Cooper & Edgett (2008) recommend *brainstorming* despite its limited popularity (17.4 percent). (Cooper & Edgett 2008)

Focus groups

Focus groups are special kinds of groups gathered together for example based on purpose, size, composition, and procedures. *Focus groups* are carefully designed conversations on a specified topic with 6-8 participants. Participants have specific characteristics valuable for the studied product / phenomena. Krueger & Casey (2000, pp.4-5) crystallize goals for the focus groups as following:

> *The purpose of a focus group is to listen and gather information. It is a better way to understand how people feel or think about an issue, product, or service.*

The field of social science questioned the quality of information collected with individual interviews in the 1930's, when interviews were still strictly structured. Interviews were seen as leading the interviewee and the results were taught to be too much influenced by the preconceived ideas of the interviewer. As a response to this problem, social scientist started to develop methods that shifted attention from the interviewer to the respondent. First *focus groups* were conducted in the 1940's and in the 1950's *focus groups* were already widely used especially in market research community. *Focus groups* were seen useful to promote participants self-disclosure and to get "under the skin" of the participants thoughts and feelings. (Krueger & Casey 2000, pp.5-8) Thus, *focus groups* were natural research method to adopt in the UCD and HCI field in general.

Customer brainstorming

Brainstorming is a group creativity method that aims to temporarily loosen participants' internal models of reality and weaken inter-concept relationships. This way, brainstorming methods allow idea creation without, or as little as possible, constraints.(Gabora 2002) Gerbert (2009) describes the value of getting rid of constraints as following:

> *When participants are able to break free from cognitive, emotional, and behavioral bounds of socially shared conceptions of what is possible, they generate novel and valuable solutions.*

To achieve the goal of breaking free of constraints, "father of the brainstorming" Alex Faickney Osborn (1953) according to Gerber (2009) presented five basic rules for brainstorming session.

1. **Generate a large quanityty of ideas:** basic idea is that the greater the amount of ideas, more likely there is found a radical or effective solution. ‘
2. **Withhold judgment:** in brainstorming, criticism is reserved for later stage of the process. Criticism should be avoided in order to make participants feel free to generate and extend new ideas.
3. **Free-wheel**: welcoming unusual ideas supports the first basic rule by enabling large amount of ideas. *Thinking outside the box* is a good example of how to solve a problem with unusual idea. *Thinking outside the box* is a phrase that can be visualized with nine dots problem Figure 27. A person is given a task to connect nine dots with four straight lines. In many case the person starts to think the solution by figuring how to connect dots without going over the imaginary box, formed by eight outer dots. It is impossible task to solve in this way. In order to solve the problem, straight lines need to extend outside the imaginary box – as an analogy, the person needs to extend her thinking to unfamiliar territory.

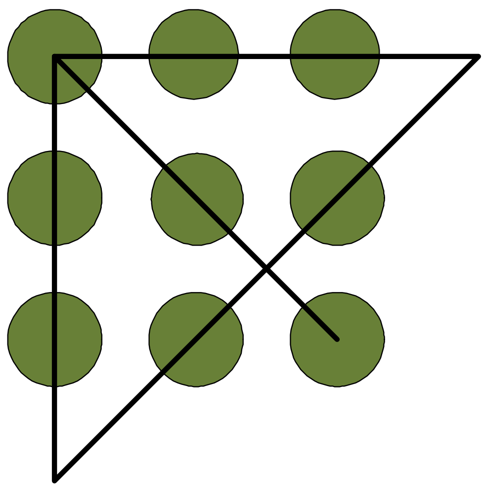

Figure 27 The nine dots problem

4. **Build on the ideas of others:** associations that come up with new ideas are welcome in brainstorming sessions. This basic rule aims to take advantages of the ideas that evoke from other participants ideas.
5. **Identify a leader:** in order to keep brainstorming sessions organized, it is important to plan carefully the structure and choose a moderator for the session.

Lead user analysis

The *lead user analysis* -technique is based on an idea that if company works with innovative customers, innovative ideas come as a result. This method often includes a group session, typically in a form of a workshop. Advantages in this method are that lead users, early adopters, are more likely to have the next new product idea. However, it is challenging to identify, who the lead users are, and recruit them to participate in a concept design process.(Cooper & Edgett 2008)

6.1.2. Context Walk

Importance of understanding the context of use is widely recognized among the HCI field. According to Oulasvirta et al. (2003), it is crucial in the design of ubiquitous technology that physical, social, interactional and psychological contexts are investigated thoroughly. Traditionally group sessions are held in office environment and for example scenarios, photos and videos have been used as a stimulus for understanding the context of use. These stimulus' are missing the "real feel" of the context that I state to be one very important part of user experience. To overcome this shortcoming of traditional stimulus, I developed *context walk* method in order to give group session participants better understanding of especially physical, social and interactional context.

During the context, walk participants are led by a researcher into the studied environment. Context walk consists of few action points where the group creates use cases. Action points can be for example ATM or bathroom if there is interest to create new use cases and study user experience in those environments. For helping idea creation, participants' needs in an action point are asked. After participants come up with a use case, one participant is asked to act out the use case while the other participants and the researcher leading the group make observations. After each acted use case, participants fill the sentence completion form. Researcher also takes pictures of each use case for helping recall the situation in the group discussion.

Context walk is quite similar with the body storming method presented by Oulasvirta et al. (2003). Oulasvirta et al. (2003) are critical towards traditional data collection methods that draw from anthropological and ethnographic research. As a result of data collection there can be scenarios, use case descriptions or systematic ethnographic transcriptions. Oulasvirta et al. (2003) stress that quality of the documents derived from collected data is overemphasized in traditional UCD methods. Documentation is also more or less result of one or few researchers' interpretations. Also in many cases amount of documentation is overwhelming. (Oulasvirta et al., 2003)

As an answer to these problems, Oulasvirta et al. (2003) present bodystorming method. Before the bodystorming session a preliminary observation and documentation is conducted. Interesting ideas and phenomena are gathered and based on the ideas design questions are formed. Bodystorming session takes place in real context were the design question occurs. Thus, designers having a design question occurring in a swimming hall will go to a swimming hall. Participants are sometimes asked to act out the use cases they create. (Oulasvirta et al., 2003)

Context walk method differs from bodystorming in couple of ways. First, the participants of context walk are not designers but selected group of end users. Second, context walk is used also to come up with new design questions not to evaluate earlier found design questions. Third, sentence completion tasks (see section 7.1.3) are given to participants in action points. Context walk is also meant to be as light as possible. This enables that the group discussion can be held right after the context walk.

6.1.3. Sentence Completion

In sentence completion, a person is asked to complete sentences that are incomplete. Goal is to gather person's first impressions and associations towards the studied subject. Sentence completion originates from a projective psychological technique. It has been used for identifying users' values and needs especially in consumer psychology. (Kujala & Nurkka 2009)

6.2. Methodology

We arranged two group sessions with six participants each. Group sessions were a combination of before introduced three VOC methods (see 6.1.1): focus groups, brainstorming and lead user analysis. The interaction of the touch-based interaction was in focus during the sessions. Our aim was to recruit technically orientated participants and experiment with context walk as brainstorming method, in order to help idea creation.

6.2.1. Participants

Background information of the participants is presented in Table 16. First session consisted of three males and three females. Second session had six male participants. Participants' age ranged from 20 years to 38 years with a mean of 25.5 years (SD 5.6). Ten of the participants were students from Tampere University of Technology or University of Tampere and two participants were unemployed. Besides the difference between sex distributions, both groups were similar according to demographic variables.

Table 16 Background orientation of group session participants

	Group session 1	Group session 2	GS1+GS2
Average age (SD 5.6)	24.8	26.2	25.5
Oldest	34	38	38.0
Youngest	22	20	20
Male	3	6	-
Female	3	0	-

We also wanted to know what kind of technical orientation users have. We aimed to have technically oriented people, so called lead users or early adopters, to participate in our study. Thus, we can get benefit from lead users' ability to create novel ideas (see 6.1.1). Figure 28 presents the results from three statements about participant's technical background on a scale of 0-7, seven being “I agree totally” and zero meaning “I totally disagree”. There were no significant differences between the groups in technical orientation.

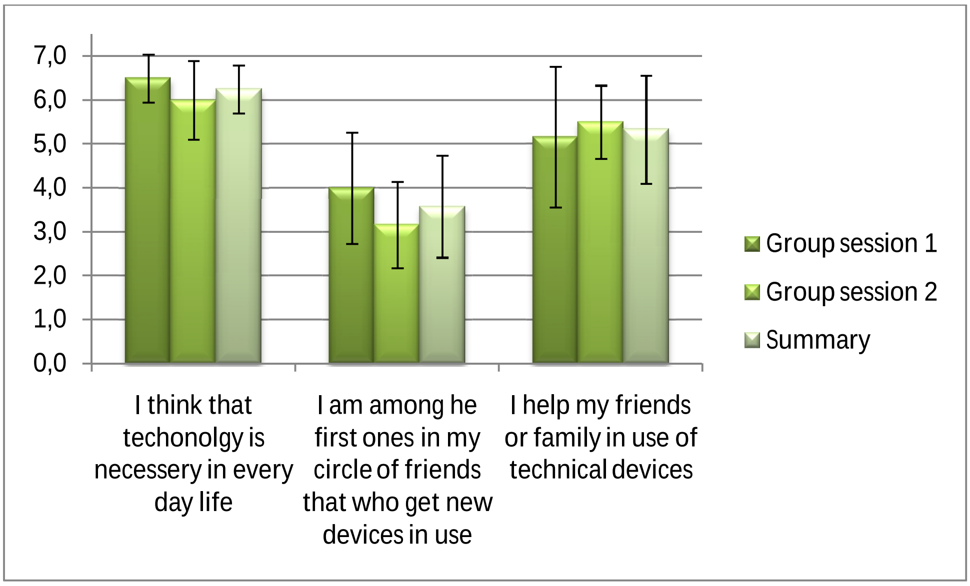

Figure 28 Technical background of group session participants. Error bars describe standard deviation. (N=12)

We reached our goal to recruit early adopters reasonably well. In summary, technology was seen very important by most of the users (mean 6.3, SD 0.5), participants also helped their friends or family relatively much (mean 5.3, SD 1.2). Participants were neutral in their answers for the third question about when they get new devices compared to their circle of friends (mean 3.6, SD 1.2). One reason for the lower score in this statement can be assumed high technical orientation of participants’ circle of friends. Participants received two movie tickets or similar complimentary gift as compensation for participating in the study.

6.2.2. **Structure of the Group Sessions**

Group sessions were divided into three phases:

1. Warm up and introduction, 15 minutes
2. Context walk , 60 minutes
3. Group discussion, 90 minutes

In the *warm up and introduction* phase, participants filled a background questionnaire (APPENDIX 2: The Background Questionnaire for the Group Sessions) in order to collect information about participants’ technical orientation and demographic variables. Participants also signed a recording agreement. After these formalities, participants were introduced to a concept of thinking outside the box in order to support participants’ freedom to invent new ideas (see 6.1.1). Then the participants were introduced with context walk method by testing the method in the meeting room. After warming up we took participants to context for an hour. Last phase of a group session was group discussion that lasted approximately 90 minutes. Schedule was tight but we managed to carry out the group session as planned. We arranged one pilot session with researchers and research assistants from IHTE. Participants received two movie tickets or similar complimentary gift as compensation for participating in the study.

6.2.3. Context Walk

Context walk phase worked as an innovation session and stimulus for the group discussion. Participants were divided into two groups of three, led by a researcher. First group (Public group) conducted the context walk in public environment at Tampere University of Technology and surroundings. Another group (Home group) was led to smart home eKoti, located at Department of Electronics at Tampere University of Technology. eKoti is a one bedroom apartment laboratory for studying smart home applications and environment (Tampere University of Technology Department of Electronics). Context walks were recorded with audio recorder for analysis and photos were taken of each use case for recalling the situation in the group discussion.

Both groups had four action points such as living room, bus stop and information board, where the group was gathered together. In each action point, participants were asked to come up with use cases for touch-based interaction with mobile phone. In order to help idea creation, users were asked what needs do they have, what kind of technologies are available, and what kind of information is available or needed, in the situation. After creating the use case(s), participants marked RFID tags with small post-it markers (Figure 29).

Figure 29 Post-it markers as RFID tags

Figure 30 Acting out the use case

When the RFID tags were marked, participants were asked to act out the use case (Figure 30). One participant was chosen to be the actor and other participants were asked to observe interaction. Actor had a turned off mobile phone that presented the NFC mobile phone. After every acted use case participants filled sentence completion form (APPENDIX 3: The Sentence Completion Form) in order to collect observations and user experiences. Use cases were named for latter identification.

6.2.4. Group Discussion

After context walk, participants were gathered into a meeting group. Every use case was presented and the photos taken during context walks were superimposed on a big screen. User experience aspects were discussed in detail. Following questions were asked for every use case:

- What was the overall impression about the use case?
- Were there some drawbacks in this use case?
- Was the use case innovative?
- Was it practical to do the task in this way?
- Is it acceptable by other people to act in this way?
- Was it easy to detect possibilities?
- Was the interaction stylish?
- Was this appropriate way to complete the task in hand?
- Was the interaction simple?
- Would you interact in this way in the future?

6.3. Analysis

6.3.1. User Experience Characteristics and Qualities Affecting User Experience

DIEM project has analyzed user experience of ubiquitous technology in DIEM environment. Analyzes are based on a large-scale literature review and eight focus group. As result of analyzes, project has identified sixteen characteristics of user experience in DIEM environments and nineteen qualities of DIEM systems that affect the experiences. The user experience characteristics represent ideal types of experiences that should be aimed at when designing DIEM smart environments. The qualities affecting user experience can be seen as features and qualities of, and requirements for the DIEM interoperable environments, affecting the user experience in DIEM environment. (Olsson et al. 2010)

In order to find out which user experience characteristics and qualities affecting user experience (further, both together are referred as attributes) were present in use cases created in the group sessions, I analyzed the answers of the sentence completion tasks and audio recordings of the group discussions and context walks. I identified positive mentions about the attributes. Overall, 22 use cases were created in the group sessions. In analysis, I combined similar use cases, so that the final number of use cases was 15.

I also identified some drawbacks from the sentence completion tasks and the group discussions. I identified ten categories of challenges of touch-based interaction.

6.4. Results: Use Cases Created in the Context Walk

Both groups had four action points presented in Table 17. Ten use cases for public context and twelve use cases for home context were created.

Table 17 Context walk action points

Action point	Public group	Use cases	Home group	Use cases
Action point 1	Shop	4	Living room	6
Action point 2	Bus stop	2	Out door	4
Action point 3	Information board	2	Kitchen	2
Action point 4	Vending machine	2	Bedroom	-

6.4.1. Living Room Use Cases

Use case 1 (UC1): "Drawing" a signal route

User "draws" the audio or video signal route by touching either tags placed on audio/video equipment or touching tags placed on a suitable surface by the user describing audio/video equipment. Signal route for audio/video signal can be controlled without using separate remote controls or adjusting amplifier switches/buttons. For example touching an mp3 player tag and then an amplifier tag and then a speaker tag, music played by mp3 player is now heard from the home speakers. Another example: user wants to watch a movie that is stored in her laptop. User touches laptop and then home multimedia amplifier and then video projector. Now laptop screen is visible on a big screen.

Figure 31 User "draws" a signal route

Use case 2 (UC2): Personal information tag

Figure 32 Personal information tag found in a person's wallet

User touches a personal tag of unconscious person and gets information about the person to her mobile phone. For example, user touches a tag found on a shirt of an unknown night guest who is sleeping on a couch morning after a wild party. On a mobile phone screen user can check the name of the guest and the favorite breakfast of the guest. Another example: a person is lying on a ground unconscious. Paramedic touches a tag found in the unconscious person's wallet and mobile phone screen shows medical and personal data about the unconscious person.

Use case 3 (UC3): Universal remote control for home entertainment system

User comes home and wants to switch on TV and adjust lighting for nice evening. User lays her mobile phone on the table and TV turns on and the lighting adjusts into the pre-configured state. User touches TV icon on a table and can now use her mobile phone as a TV remote control. Same way user can control stereos, lightning, curtains etc.


Figure 33 Using mobile phone as a TV or slideshow remote control

Use case 4 (UC4): Mobile phone board game

Interactive table surface works as a board game board and mobile phones work as pieces. Table recognizes the position of mobile phones and online content can be used in a game. This enables novel game ideas.

Use case 5 (UC5): Sharing multimedia content

User is visiting her friend. User has pictures of the vacation they took together last month in her mobile phone. User opens picture folder in her mobile phone and touches a tag on the TV. Slide show starts on the TV and user can control the slide show with her mobile phone. User wants to show some pictures also from her internet archive and touches a “Wi-Fi tag” to form internet connection automatically.

Use case 6 (UC6): Book and CD record archive

Figure 34 User touches bookshelf

User writes a search word for the book/CD she is looking for. User touches a tag placed on a bookshelf and gets information on her mobile phone whether the book is found and what is the location of the book. For example user is visiting her friend and they are discussing about the interesting book user’s friend read year ago. User’s friend does not remember whether she still has the book. User writes the name of the book on her mobile phone and touches the tag on the bookshelf. User’s mobile phone screen shows that the book is found in the bedroom bookshelf.

6.4.2. Kitchen Use Cases

Use case 7 (UC7): Recipe and price comparison

At home, user downloads a recipe in to her mobile phone by touching a tag on a cooking book. When entering the shop user touches a certain tag and gets location, price and other information about the ingredients of the recipe.

Use case 8 (UC8): Home appliance instructions


Figure 35 User uploads dishwasher instructions

User touches a tag placed on a home appliance and gets short instructions how to use the home appliance on her mobile phone screen. For example user is house sitting her friend’s apartment while the friend is on a vacation. User is trying to figure out how to use the microwave oven. User touches a tag placed on the microwave oven and simple instructions are shown on the user’s mobile phone screen.

6.4.3. Door Use Cases

Use case 9 (UC9): Home automation system control when leaving an apartment

Figure 36 Touching a tag when leaving an apartment

When user is leaving her apartment she touches a tag beside the door. Home automation system (HAS) switches off the lights and defined home appliances such as oven or other safety critical home appliances. HAS also gives reminder if there is a need to empty trash pins. It is also possible to download shopping list to the mobile phone. Shopping list is formed automatically by HAS and completed by the user.

Use case 10 (UC10): Door code

User touches a tag beside the door and gets single- or multi-use code in to her mobile phone for entering the apartment. For example, neighbor is leaving on a holiday and user has promised to look after neighbor's plants. User touches the tag placed beside the outdoor inside the neighbor's apartment. User gets certain amount of entrances pre-programmed by the neighbor to the neighbor's apartment.

6.4.4. Shop Use Cases

Use case 11 (UC11): Product navigation in a shop

User touches a tag of desired product on a billboard in front of the shop. User gets a map of the shop in to her mobile phone. Route to the product is shown on the map.

Figure 37 User gets a map to desired product

Use case 12 (UC12): Finding alternative products in a shelf

User wants to compare alternative products in a grocery store. In the end of the shelve user touches a tag for a certain product such as wheat flower. Price etiquettes of wheat flower products start to blink and user finds alternative products easily. User can touch also different categorizing tags such as lowest price, or organic products and then only etiquettes of the lowest price or organic produced wheat flowers start to blink.

6.4.5. Vending Machine Use Cases

Use case 13 (UC13): Lunch vending machine

Figure 38 User choosing a lunch

User selects desired lunch from a vending machine by touching a tag allocated for the product on the vending machine. There is extra information about the product shown on user's mobile phone screen, such as calories, ingredients etc. User buys the product by touching the "buy" tag, and enters the pin code on her mobile phone. User picks up the lunch, touches the tag on the product, and puts the meal inside nearby microwave oven. User touches a tag on the microwave oven, the lunch is heated default time, and power set by the manufacturer of the lunch.

6.4.6. Electronic Information Board Use Cases

Use case 14 (UC14): Electronic information board

Figure 39 User controls electronic info board

User controls the navigation of an electronic information board by navigation tags placed on the information board. User can download information about current event shown on the information board by touching a certain tag on the information board. User can also by tickets to the events by touching a certain tag. For example, user's friend told her about the good new band that has a gig in town next weekend. User goes in front of the electronic information board and touches tags "this week" and "gigs". Electronic information board shows all the gigs that are held in town this week. User chooses the right gig by navigating through gigs with navigation tags found next to the information board. After selecting the right gig, user downloads extra information, such as link to the bands homepage, to her mobile phone by touching a certain tag. User buys tickets by touching "buy tickets" tag. User chooses the amount of the tickets by navigating in the information board's graphical user interface with navigation tags and confirms the payment with her pin code.

6.4.7. Bus Stop Use Cases

Use case 15 (UC15): Bus stop

User touches a tag that is located inside a bus stop shelter beside a route map. User gets timetable of the next arriving buses in to her mobile phone screen. User can also touch route map and select the start and end point of her bus trip. Route information is shown on user's mobile phone screen.

Figure 40 User selecting bus route

6.5. Results: Findings on User Experience

Table 18 & Table 19 present the evaluation of sentence completion tasks and group discussion referred to user experience attributes, recognized in DIEM project. Table 18 presents the user experience characteristics and Table 19 presents the qualities that affect user experience. Numbers describe how many times an attribute was mentioned in a positive way.

Thirty-one out of thirty-five attributes were mentioned in a positive way. Attributes that were not mentioned or got only few mentions were mostly attributes that simply were not possible to be present in formed use cases. For example, there was none or only little *social functionality* in use cases. Other reason for some attributes mentioned seldom was limited amount of sentence completion tasks and limited time in the group discussions. For example, attribute *agency* that was only mentioned once is an attribute that should have been asked explicitly.

Table 18 Characteristics of User Experience in DIEM Environments

			Use case															
	Elements	Short description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sum
1	Collectivity	Participating by sharing or joint activities				1	1	1										3
2	Connectedness	Being able to connect with other people		1		1												2
3	Social Awareness	Being aware of socially relevant occurrences		4													1	5
4	Empowerment	Feeling of being able to achieve and reach goals	1			1												2
5	Convenience and Comfort	Feeling of getting something done effortlessly	2	1	3	1			1	2	6	1	4	2	7	3	4	37
6	Agency	Whether the environment is seen as an entity or tools			1													1
7	Autonomy	Being in control of one's own actions	1							1				1			1	4
8	Feeling of control	Being able to control actions of a SE	1		1													2
9	Feeling of trust	Being able to trust the SE and its services	1									1			1			3
10	Naturalness of Interaction	Intuitive, human-like interaction	1						1									2
11	Excitement & Engagement	Feeling of being tempted and captivated		1			1		1			1						4
12	Fun	Feelings of joy, amusement and playfulness				3									1			4
13	Surprise	Pleasurable surprises, SE surpassing expectations												1		1		2
14	Feeling of being monitored	Feeling of being under surveillance																0
15	Feeling of efficiency	Being able to work quickly and with no errors	2		3	1	2	2			2		3		3	3	3	24
16	Heureka! (Discovery)	Feeling of gaining insight					3		2		1	1		1	1		2	11

Because of qualitative nature of the data, it was challenging to identify attributes and it needed interpretation. For example when participant mentioned that the interaction and use case was "easy" or "comfortable", I interpreted that attribute *comfort and convenience* was present. Furthermore, when participant mentioned that it was convenient that tag was placed in a good position next to the door, I interpreted that the attribute *physical comfort* was present. For the combined use cases, I counted all the mentions for original use cases.

Table 19 Qualities of DIEM Systems that Affect the Experiences

			Use case															
	System/Context properties	Short description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Sum
17	Attention Division	How largely is the user able to focus on SE						1										1
18	Affordance Perception	Perception of cues of possibilities in the SE											1			2		3
19	Affordability and Availability	Price and availability to general public	1															1
20	Appropriateness	The manner and time of service offered	1		1	2		1		4			1		2		2	14
21	Ease of Learning	How fluently the SE can be adopted	1		1	1	1	1										5
22	Feedback	Quality of feedback from the SE																0
23	Predictability and Consistency	How predictable SE's services functions are	1															1
24	Reliability	Reliability of the SE's actions and information	1							2								3
25	Modifiability	How much the user can personalize the SE							2		1							3
26	Openness	Openness for development and change			1		1								1	1		4
27	Physical Ergonomics	How physically taxing is the use	1	1	2		2			1	2			1			1	11
28	Automation & Pro-activity	How proactively the SE's services act	1		2		2				1	3						9
29	Role of Technology	The "social" roles that the services are given																0
30	Modalities of Interaction	Quality and type of senses for interaction	2		1	1							1		3	2	4	14
31	Relevance	Relevance of the information to the user	1			1	1	1	2	1	2		1		2	2	3	17
32	Privacy Policy	Privacy burden vs. benefits from use										3			1	1		5
33	Novelty	How new the content is for the user	1			4	4	1	1			1	2	2	1	1	1	19
34	Social Functionalities	Type and availability of social tools																0
35	Dynamic	Describes the continuous change of SE	1			2	2							1			1	7

Four of the characteristics and qualities, *feeling of being monitored*, *feedback*, *role of technology* and *social functionalities*, were not mentioned. Twenty-one attributes got one to five mentions. *Automation and pro-activity* and *dynamic* were both mentioned seven times. Most interesting are the attributes that got over ten mentions in results. These attributes were *convenience and comfort* with 37, *feeling of efficiency* with 24, *novelty* with 19, *relevance* with 17, *modalities of interaction* and *appropriateness* with 14 and *physical ergonomics* with 11 mentions.

Convenience and comfort

Convenience and comfort was mentioned altogether 37 times. Most of the mentions were that it was easy to do the task according the use case. Many times when *convenience and comfort* was present also the *automation and pro-activity* was mentioned. Simple interaction together with automated data gathering or highly automated processes was seen as positive use cases. For example, UC9 *automation system control when leaving an apartment* had six mentions in *convenience and comfort* and three mentions in *automation and pro-activity*. In UC9, many normal operations that are performed when leaving an apartment such as switching off the lights, checking that home appliances are turned off and do the trash pins need emptying were automated. Interaction was simple and needed only touching a tag beside the door. UC13 *lunch vending machine* got seven mentions in *convenience and comfort*. A participant filled in the sentence completion task as follows:

> *"This interaction was fascinating because payment is easy and heating a lunch is simple".*

Feeling of efficiency

Feeling of efficiency was mentioned altogether 24 times. This was the most obvious attribute direct mentions to. Mentions were for example that this way the task is done more efficiently or it makes the task completion faster. Ten out of fifteen use cases were mentioned to feel efficient with one to three mentions. This supports the results from the first study in laboratory. Touch-based interaction is efficient way to interact with surrounding environment.

Novelty

Nineteen mentions were identified for the attribute *novelty*. UC4 and UC5 got four mentions and nine other use cases got one to three mentions. For UC4 *mobile phone card game* one participant filled in a sentence completion task as follows:

> *"This was better way to do the task compared to current way, because for example trivial pursuit questions could be read from the mobile phone screen and this enables new interactive games. This is fun novel way to spend time and enjoy."*

For UC5 *sharing multimedia content*, one participant mentioned in the group discussion that interacting in this way; other people would see him as so-called lead user or early adopter and fun person.

Relevance

Relevance got mentions in eleven out of fifteen use cases ranging from one to three mentions. *UC15 bus stop* was only use case that got three mentions. Participants mentioned that the information is relevant, for example if the bus is running late, user could get up-to-date information quickly and easily to her mobile phone. One participant told that he takes his mobile phone out of his pocket anyway almost every time on a bus stop to check the time so it is not much more effort to check the route or arrival of the next bus.

Modalities of interaction

Modalities of interaction got 14 mentions. This attribute was identified when participant mentioned that the touching itself was something positive. UC15 *bus stop* got five mentions and six other use cases got one to three mentions. For UC15 one participant filled a sentence completion task as following:

”Interaction was simple because
I can pick up the timetable by simply touching a tag.”

Touch-based interaction with mobile phone was seen as a good way to interact. It was seen natural and simple.

Appropriateness

Appropriateness got also 14 mentions. UC8 *home appliance instructions* got four mentions and seven other categories got one to two mentions. In the group discussion, one participant mentioned that it would be very appropriate to have instructions available always when they are needed and other participant emphasized that it would be nice feature because there were no more need to look for the manual.

Physical ergonomics

Last attribute that got over ten mentions was *physical ergonomics* with 11 mentions. For example when we discussed about the UC1 *drawing a signal route* participant said that if the tags were placed close to the sofa it would be nice because the amount of movement needed would be much more smaller than doing the task in current way. Placing the tag near the door in UC1 *door code* was mentioned couple of times to be convenient.

6.5.1. Challenges of Touch-based Interaction with Mobile Phones

Table 20 presents the challenges of touch-based interaction with mobile phones gathered in the group sessions. Most of the challenges are results from the sentence completion task: “*Disadvantages in this interaction were...”*.

Table 20 Drawbacks in use cases

Category	Participants comments	Use cases found
Social context	As a family man I can say that this will not work	UC3: Universal remote control for home entertainment system
	Absence of social contact with clerks	UC11: Product navigation in a shop
	When everybody is using system same time there will be a disco	UC12: Finding alternative products in a shelf
	It can be hard when there are lots of users present. How to know is it my product blinking?	UC12: Finding alternative products in a shelf
	How does this work if bus stop is crowded?	UC15: Bus stop
Physical context	Tags require too much space near the sofa	UC1: "Drawing" a signal route
	Size of the mobile phone as pieces.	UC4: Mobile phone board game
	Where to place the tags?	UC7: Recipe and price comparison
Technology maturity	How can we make system so that it is comprehensive?	UC9: Home automation system control when leaving an apartment
	How is the positioning possible indoors?	UC11: Product navigation in a shop
Reliability	Is the identification reliable?	UC2: Personal information tag
	Is the information up to date?	UC6: Book and CD archive
	If the technology fails, how can I open the door?	UC10: Door code
	What if the microwave oven does not recognize the product?	UC13: Lunch vending machine
Security	There is danger that privacy is lost.	UC2: Personal information tag
	Security is in a danger if you can also pay with this system	UC7: Recipe and price comparison
	There are security aspects that have to be considered.	UC10: Door code UC13: Lunch vending machine
Information presentation	Is mobile phone screen suitable for presenting this kind of information?	UC6: Book and CD archive UC8: Nome appliance instructions
Device dependency	Normally I do not carry my mobile home with me when I am home	UC3: Personal information tag
	Dependency on one device when there is too much integrated in it. What if the device gets lost or breaks down?	UC3: Personal information tag UC9: Home automation system control when leaving an apartment
Techno-criticism	I would not like to admit that I need this technology.	UC3: Personal information tag
	Does this make people too technology dependent? Why people walk in the woods? I think traditional board games might be more fun.	US4: Mobile phone board game
	I think creativity in cooking might reduce.	UC7: Recipe and price comparison
Interaction accuracy	I might get a wrong product.	UC13: Lunch vending machine
	Is it possible to touch the map accurate enough?	UC15: Bus stop
Interaction feels/looks awkward	It might look stupid when you start to press mobile phone buttons this much in a shop and do not look around you.	UC11: Product navigation in a shop
	Other people could get disturbed if you hassle with your mobile phone in a crowded bus stop.	UC15: Bus stop

Social context

Especially public context was found difficult according to social context. Participants thought that interacting with NFC phone in a crowded place might be difficult and if there were multiple users it might make controlling for example electronic information board difficult.

Physical context

In couple of use cases, physical placement of the tags was seen as challenging. Tags might require too much space in home context and mobile phones were found a bit large to act as pieces in a board game.

Technology maturity

Technical background made some participants doubt if the technology was mature enough. Absence of NFC devices was seen as a challenge as well as some technical issues that were not precisely NFC related. Few participants for example doubted that it is not yet possible to navigate accurately indoors with a mobile phone.

Reliability

Information and technical reliability was seen as a challenge. Information offered needs to be accurate and up to date for example in book and CD archive. One participant wondered how she can warm up the lunch if the microwave oven in UC9 does not recognize the meal or how the neighbor can enter the apartment if the technology fails in UC10.

Security

Security was found as important aspect especially in use cases that included paying (UC7 and UC13). Also personal information should be secured in some way (UC2 and UC10).

Information presentation

Few participants doubted if the mobile phone screen was suitable for presenting larger amount of information. Thus, for example reading home appliance instructions from a mobile screen might not arouse positive user experience (UC8).

Device dependency

One of the most challenging aspects was the dependency on a single device. If a mobile phone is wallet, door key, remote control etc. what happens when the mobile phone gets lost or breaks down (UC3 and UC9). Participants thought that there should always be a backup system for this situation.

Techno-criticism

Some participants were afraid that people might get too attached in technology. If everyday activities like procedures when leaving an apartment are automated, are we going to lost contact to the “real world”? In addition, there was some criticism towards getting more and more information all the time. Is there any more possibility to recognize important information from the huge amount of information offered to the user automatically?

Interaction accuracy

In two use cases participants were suspicious whether touch-based interaction is accurate enough in the use cases. One participant thought that he might get a wrong product from the vending machine (UC1). Many participants were wondering if it was possible to check the bus route from the map because they thought it is not accurate to select the starting point and destination of the route.

Interaction feels/looks awkward

Some public use cases were seen challenging because the interaction was thought to look awkward. If user needs to touch tags or hassle with a mobile phone like one participant mentioned in a crowded place, user might feel herself awkward (UC14 and UC15). Also staring at the mobile phone was seen impolite and awkward in a shop context (UC11).

6.6. Summary

In the group sessions 22 use cases were created and some elements of user experience with touch-based interaction was identified. Touch-based interaction was seen efficient and appropriate way to interact in both public and home environments. It was also seen as an innovative and novel way to interact. Participants described what other people think of them if they use touch-based interaction with NFC enabled mobile phone for example as follows: *“modern, forerunner, clever, technology-aware and MAC-person who has all the solutions behind one button”.*

Participants were the most concerned about the device dependency. Too much features integrated in one device was seen problematic in case of malfunction or losing the device. The security issues were seen very important especially for the use cases that included payment, ticketing and access control. For example a comment from the group discussion:

”I would rather like the money to be stored in external database than in mobile phone, in case my phone gets lost.”

In addition to device dependency and security issues, interaction in social context in which other people are present was seen challenging. Touching environment with mobile phone might raise doubts in unfamiliar people and multi-user situations can be difficult. The tag placement should be considered carefully in order to avoid crowded places or blocking passages.

7. CONCLUSIONS

This thesis describes the applied methods and results of two studies arranged for measuring user experience of touch based interaction with mobile phones. The first study conducted in usability laboratory aimed to compare user experience of touch-based, speech, and gesture human-computer interactions in the Home Media Center context. In order to broaden the scope from measuring traditional usability issues such as efficiency and effectiveness, the thesis presents metrics for measuring hedonic qnd emotional aspects of user experience as well.

The group sessions aimed to gather novel use cases for NFC mobile phones as well as to gather information of user experience of touch-based interaction. In order to give participants good understanding of the context of use that is important factor defining the user experience we used context walk method as a stimulus in the group sessions.

In this last chapter of the thesis I present the conclusions I made from the research, I discuss the validity and reliability of the research and outline the future work that this research inspires.

7.1. User Experience of Touch-based Interaction with Mobile Phones

Results from the conducted studies support the previous research that has found touch-based interaction with NFC technology very efficient and intuitive. In the laboratory tests touch-based interaction was found the most efficient and effective compared with speech and gesture interaction in both subjective and objective measures. It was also seen as the most practical and simple. Analysis of the group sessions shows that *feeling of efficiency* was mentioned in a positive way in thirteen out of fifteen created use cases.

Touch-based interaction was clearly seen as stimulating and novel interaction technique in a positive meaning. Touch-based interaction was seen the best interaction technique compared to speech and gesture in all but one hedonic attribute measured in laboratory tests. Gestures were seen classier than touch-based interaction but touch-based interaction was clearly in the zone of tolerance in classiness as well. In the group sessions, some participants criticized the interaction as stupid looking and that NFC user interfaces make life too technology-centered. Touch-based interaction was seen very *acceptable by others* and *stimulating*, that is, *exciting* and *innovative*. Novelty of touch-based interaction was mentioned in eleven out of fifteen use cases in the group sessions.

The results from the laboratory tests show that interaction possibilities were visible for the users in our prototype. In previous studies, it has been noticed that it is very important that affordances are visible in NFC user interfaces. Thus, we tried to offer clear affordances in our prototype. We for example divided the platform with background colors depending on the type of functions on certain area.

The results are a good indicator that touch-based interaction should be considered when designing novel user interfaces for smart home environments. Touch-based interaction was seen as the most suitable for Home Media Center context in laboratory tests. In the group sessions, there was criticism towards the space that RFID tags require especially in home context. Participants were also somewhat skeptic if the interaction is accurate enough. However, *convenience and comfort* was the most often mentioned characteristic of user experience in use cases created in home context during context walk.

Touch-based interaction is appropriate and acceptable interaction method that produces positive user experiences. Overall user experience and acceptability of touch-based interaction were evaluated to be positive compared to expectations in laboratory tests. Most of the use cases created in the group sessions were seen as *appropriate* and *relevant.* Touching was also found good *modality of interaction* with positive mentions in fourteen out of fifteen use cases. Positive user experiences were related to the *novelty, efficiency of use, discovery* and *ease of use.*

The biggest concern towards NFC user interfaces was the device dependency. Participants of the group sessions were especially worried what happens, if the NFC enable mobile phone breaks down or gets lost, when it is used non-stop in every-day life.

Security issues raised concerns as well, especially in the use cases with payment and access control features. Even though payment with NFC enabled mobile phone was seen simple and efficient, participants emphasized the importance of security in these use cases. Personal identification number (PIN) was the most often proposed solution to this challenge.

In summary, touch-based interaction with NFC enabled mobile phone was seen efficient and novel interaction technique that is suitable for variety of domains and applications. Touch-based interaction with NFC mobile phones can raise positive feelings, such as *excitement* and *discovery*, and produce positive experiences for the users, as long as *security, reliability* and issues related to *device dependency* are carefully designed.

7.2. Study Methodology

7.2.1. Applied SUXES method

Measuring hedonic aspects of user experience with SUXES method seems promising. In order to study hedonic aspects of user experience, I developed metrics to be used with SUXES method. Participants found the used statements easy to answer with the exception of the statement *"This interaction style brings me closer to other people"* which was excluded from the analysis.

The results from the laboratory tests supported the results from the group sessions. For example, in laboratory tests, touch-based interaction was found innovative and novelty was one of the most appreciated qualities of touch-based interaction according to the results from the group sessions.

All the participants found the animations match real usage situation quite accurately and animations were thought to be simple enough for introducing the UIs. In the post-test interviews, we asked users, did they get realistic picture of the different interaction styles on the grounds of the introduction animations.

7.2.2. Context Walk

Context walk method, proved to be a good method for innovating novel use cases for touch based interaction with mobile phones. All together twenty-two use cases were created during relatively short time. Number of novel use cases indicates the need for further studying the possibilities of NFC.

Context walk works as an inspiring stimulus for a group discussion. Participants were eager to comment and debate in the group discussion based on their experiences from the context walk. Researcher that was assisting in the group sessions and has previous experience from other focus groups said that the participants were surprisingly talkative during the group discussion.

Acting out the use cases helped the participants to perceive the interaction in three-dimensional space. This was especially useful when physical ergonomics and social aspects of interaction were discussed. Comments like, "*it can be too crowded inside the bus stop shelter*" or "*tags need to be within reach*" support this conclusion.

7.3. NFC Domains and Applications

Broadening the use of NFC technology from payment, ticketing and public transport applications that are the main domain is promising. All together twenty-two use cases were created in the group sessions, nine for home context and thirteen for public context. Use cases ranged from single-touch interactions as getting information about a person by touching her personal information tag to more complicates use cases such drawing the signal route for home multimedia devices.

7.4. Discussion

The main goals for this thesis were to investigate user experience of touch-based interaction with mobile phones and to investigate methods for evaluating user experience. Many aspects of user experience were discovered and studied and the results supported previous observations of the efficiency and ease of use of touch-based interaction with NFC devices found in literature (Rukzio et al. 2006; Geven et al. 2007; O'neill et al. 2007; Iglesias et al. 2009; Hardy & Rukzio 2008; Philips Semiconductors, 2006). Hedonic aspects of the user experience were also studied. Consistency among the results for hedonic attributes in laboratory tests and supporting results from the group sessions indicate that measuring hedonic aspects of user experience in laboratory seems promising.

The SUXES method (Turunen et al. 2009a) does not give absolute truth about the user experience of different interaction techniques. It is especially suitable for iterative development and prototyping. Findings from the SUXES method should be used to recognize problems or good solutions of different user experience qualities. When comparing different modalities it can indicate what modalities are suitable for the certain tasks and where the further development is needed.(Turunen et al. 2009a) For example if Nintendo Wii game is under development and laboratory tests with SUXES method indicate that the game scores low or even below the zone of tolerance in *hedonic quality stimulation* for the use of gestures with Wii remote control, there should be serious consideration of developing the gestures more stimulating. For the pragmatic quality, the conclusions are even more straightforward. For example if touch-based interaction gets negative measure of service adequacy (MSA) score in robustness, reasons for this should be studied carefully.

Group sessions that used context walk method as a stimulus produced large number of use cases for the touch-based interaction with mobile phones. The participants were also quite active in the group sessions. Oulasvirta et al. (2003) compared their bodystorming mehtod with traditional brainstorming session. Bodystorming has lots of similar features with context walk. Oulasvirta et al. (2003) found that there were no differences in the amount of ideas, and the quality of use cases created during the sessions. Nevertheless, they noticed that several ideas that were created in bodystorming sessions were “reinvented” in later phases of the development. Thus, this is is an indicator that the ideas from bodystorming sessions were highly memorable and inspiring. (Oulasvirta et al., 2003) This supports our perceptions during the group discussions. Use cases were even re-acted in the group discussions and discussion was lively and enthusiastic.

7.5. **Validity and Reliability**

Most of the data during the research was qualitative in nature. This raises the question of the validity and reliability of the research. The participants in the studies were mainly technically oriented students in their twenties. Thus, it is not possible to say anything about the user experience of the touch-based interaction for more versatile population. It is possible to state that touch-based interaction seems to be is efficient and novel interaction technique that gives good user experiences for young technically oriented people.

The SUXES method used in laboratory tests is rather reliable, because the same evaluation process can be used again with same metrics in the same context. In the applied SUXES method the role of the moderator was somewhat bigger than in the original SUXES method developed by Turunen et al. (2009a). The moreator needs to be as consistant as possible between the tests. Otherwise, the reliability of the results can decrease. Order of the tested user interfaces were counterbalanced and satements in the questionnaires were randomized. This was done in order to improve the reliability of the study.

Touch-based interaction seemed to be superior compared to speech and gesture in the laboratory tests. Low accuracy in speech recognition compared to previous studies (Turunen et al. 2009c; Turunen et al. 2009d), raises discussion about the validity of the comparison. Especially the results of the pragmatic qualities of the user experience should be questioned. Low speech recognition influenced obiously to the participans' evaluations of the robustness of speech which had clearly negative MSA measure. It also had big influence on the effectivenes and efficiency of the speech. I assume that low speech recognition accuracy did not effect as much to the evaluations of the hedonic quality. The evaluation for the hedonic qualities of user experience were in the upper half of the zone of tolerance, thus participants' expectations for speech were met.

Laboratory tests measured only the user experience for the first time use of the Home Media Center. Thus, it is not possible to figure out what is the user experience for long time use of the Home Media Center. However, the measuring was focused on use of different modalities and interaction techniques. Thus, we can make conclusions of what is the user experience of the compared modalities and interaction techniques in this context.

In the group sessions, the results were gathered with sentence completion tasks and analyzing audio recordings from the group discussions, and further transformed into quantitive form. Thus, the results are not supposed to be interpreted as the absolute truth but as a guideline for what user experience attributes are present in touch-based interaction with mobile phones. Many characteristics and qualities of the DIEM user experience framework were mentioned in positive way. Thus, this indicates that many important features of the DIEM environment are present in touch-based interaction with mobile phones. These results should be carefully considered because the validation of DIEM environment user experience attributes is still in progress. The amount of the sentence completion tasks was relatively small and there for it was not possible to ask about certain attributes explicitly. However, the results from the group sessions show that the most mentioned eight attributes are definitely present in the touch-based interaction with mobile phones.

7.6. **Future Work**

This thesis presents the results and methodology for measuring user experience for touch-based interaction with mobile phones using near-field communication technology. These methods can easily be implemented for other interaction modalities and techniques as well. Metrics for measuring hedonic qualities with SUXES method should be developed further and validated. Appeal and aesthetics of the product can also be measured with SUXES method. This is more convenient to do with almost ready products or prototypes that have almost ready appearance. Validation can be done with more depth interviews with users about the results of the evaluation. Validation can be done also when SUXES method is iteratively used during the product development. It would be also interesting to use SUXES method with longer time use. How the user's evaluations differ from the first time use after one month, six months and one-year period of use?

Context walk method appeared inspiring for both the researchers and the participants. It was a productive innovation method. Its use in measuring and identifying the user experience of an interaction technique can be questioned. By further developing the sentence completion tasks and presenting explicit questions of user experience qualities that the researcher are interested in, in the group discussion phase, the results can be more valid and productive. It would be also interesting to include improvisation to the method. Improvisation have been noticed to enable participants to "*break free from cognitive, emotional, and behavioral bounds socially shared conceptions of what is possible, they generate novel and valuable solutions*" (Gerber 2009).

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APPENDIX 1 THE SUXES BACKGROUND QUESTIONNAIRE

First name:

Family name:

1. Age:
2. Gender: ☐ Male ☐ Female
3. Have you used Nokia N-series mobile phones?
4. Have you used Nokia 6000 series mobile phones?
5. Have you used other smart phones?
6. When I watch TV there is other people present

Always all usually / Often / Rarely/ Never or really rarely

How often do you use following applications:

7. Mobile phone applications that you havwe to install yourself

(for example. Widgets, Google Map, Calendar syncronization).
Daily/ Weekly / Monthly / Couple of times in a year / I have not used

8. Www- tai wap-browser on your mobile phone

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

9. Speech recognition feature with your mobile phone

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

10. Speech recognition elsewher

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

11. Gsture recognition (For example Nintendo Wii or Airmouse)

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

12. Gesture recognition with your mobile phone

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

13. RFID applications (for example smart bus card or access control cards)

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

14. RFIDapplications with your mobile phone

Daily/ Weekly / Monthly / Couple of times in a year / I have not used

Please indicate your level of agreement 1 = Totally agree, 4 = Ei Neutral, 7 = Totally disagree

		1	2	3	4	5	6	7	En osaa sanoa
15	I think technology plays an important role in my life								
16	I am among the first ones in my circle of friends taking new devices, online services or technical solutions in use								
17	I help my friends and family with technical problems								

APPENDIX 2 THE BACKGROUND QUESTIONNAIRE FOR THE GROUP SESSIONS

1. Age: ______
2. Gender: ___________
3. Profession:_____________

Choose the appropriate choice:

I use RFID applications (for example bus smart card, or access cards)
Daily / Weekly / Monthly / Couple of times in a year / I do not use RFID applications

What applications have you used?

____

____

I use RFID applications with my mobile phone
Daily / Weekly / Monthly / Couple of times in a year /
I do not use RFID applications with my mobile phone

What applications have you used?

____

____

Please indicate your level of agreement with each statement

1= Totally disagree 4=Neutral 7= Totally agree

	1	2	3	4	5	6	7	Can not answer
I think that technology is necessary in everyday life	○	○	○	○	○	○	○	◉
I am among the first ones in my circle of friends taking new devices, online services or technical solutions in use	○	○	○	○	○	○	○	◉
I help my friends and family with technical problems	○	○	○	○	○	○	○	◉

APPENDIX 3 THE SENTENCE COMPLETION FORM

This was better way to do the task compared to current way, because...

Disadvantages in this interaction were..

This interaction was fascinating because...

When I interact in this way, other people think I am...

Interaction was simple…

About this interaction I would tell my friend that...